

**MANUFACTURING TECHNOLOGY MANAGEMENT: KEY ISSUES  
IN THE ADOPTION, IMPLEMENTATION AND EVALUATION OF  
ADVANCED MANUFACTURING TECHNOLOGY**

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## **ABSTRACT**

Over the past decade, the declining competitiveness of U.S. and European manufacturers had received considerable attention. Various studies have documented their weakening competitive position in global markets; the decline of their manufacturing base; and the continued closure of manufacturing plants in U.S. and Europe. Attention has been focused on manufacturing strategy and technological innovations in manufacturing as providing possible solutions to these growing problems. The adoption and implementation of new manufacturing technologies, known collectively as advanced manufacturing technology (AMT), has offered the promise of successfully competing in global markets. Specifically, these technologies have offered advantages in the areas that U.S. and European manufacturers need to address: flexibility, quality, shorter product life cycles, and shorter product development cycles. However, there are two major concerns: (1) U.S. and European manufacturers have been slow to adopt advanced process technology, and (2) those firms which did adopt these new technologies have had limited success in their implementation.

In spite of its growing importance in manufacturing, management generally has limited experience with AMT and few guidelines to assist them in the transition from the factory of today to the factory of the future. This research study aims to provide an in-depth, integrative approach to addressing the issues involved in the adoption, implementation and evaluation of AMT by focusing on the experience of organisations pursuing a strategy of automation.

Using a multiple case research methodology at plant level, the first part of the study investigates the reasons why European firms choose to adopt advanced manufacturing technologies and the decision making process involved in justifying them. In addition, this study identifies obstacles to justification and provides an understanding of how firms have either ignored or overcome these obstacles. The decision to adopt AMT is only the first step in becoming or remaining competitive. Such technologies need to be successfully implemented to achieve desired benefits. The study also investigates how firms managed their AMT implementation and the obstacles that were encountered. In addition, those factors that contribute to or impede the successful implementation of AMT are identified. The

difficulties of performing post-implementation evaluations by these firms are also examined. Emphasising the use of automation as a management decision concerned only with manufacturing is not sufficient. Wider issues in the management of manufacturing technology also need to be addressed. This study highlights the importance of top management involvement in new technology development, time-based competition, and outsourcing of technology in the management of manufacturing technology. It is hoped that by offering general explanations of the key issues in the management processes of adoption, implementation and evaluation of AMT, management will be assisted in their future efforts in dealing with these processes.

The participating firms identified both individual and synergistic benefits from the application of AMT in the competitive performance measures in manufacturing, cost, quality, delivery, and flexibility. They also underscored the importance of incorporating technology management issues while formulating business strategies, because these issues were believed to influence the business performance measures, profitability level, generation of increased sales, and creation of new opportunities and facilities. Using questionnaire surveys of the participating firms, the second part of this study explores the relationships between the management processes of AMT and performance measures in manufacturing, and between some factors of effective management of technology identified in this study, and the business performance measures of a firm. Tests of hypotheses formulated confirm that the perceived benefits in manufacturing performance could be achieved. Additional statistical analyses show that, through effective management of technology, the business performance measures of a firm could be improved.



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# CHAPTER 1

## INTRODUCTION

### 1.1 BACKGROUND

Advanced Manufacturing Technology (AMT) plays a major role in productivity improvements in manufacturing organisations. The automated "factory of the future" is seen as the essential ingredient for competitive success in world-wide markets. Hayes and Wheelwright (1984) propounded that investment in advanced process technology would strengthen the competitive edge of U.S. manufacturers. The notion of technology as a competitive weapon is also gaining momentum because of the rapid introduction of new products, new processing methods and work practices, changing customer needs and demands, including varying extents of product support and after-sales service (Bessant, 1994).

AMT offers advantages in areas that would enable manufacturers to survive the onslaught of competitive pressures. To meet the challenges of the new strategic environment, firms need to address the following (Skinner, 1985; Galbraith, 1990; and Cardone, 1993):

- \* competitive production costs for reduced run lengths and increased product mix.
- \* superior, reliable, consistent quality.
- \* ability to reduce unit cost with reduced volume.
- \* ability to introduce new products quickly.
- \* ability to change over products without delay.
- \* adequate return on investment.
- \* competitively short production cycles.
- \* competitively short delivery delays.

In spite of widely publicised claims of the positive benefits associated with automation, adoption of AMT by major manufacturers has been slow. To date the number of manufacturing organisations adopting and implementing AMT has been modest. There are reports that many implementations have resulted in failure (Bessant, 1993). The fact remains that there are significant

risks associated with adoption and implementation of such complex integrated manufacturing systems. Organisations are committing considerable resources, both financial and human, to attain competitive success through factory automation. However, they may not always have a clear understanding of the management process required to achieve success (Ross, 1991).

There are three stages in the process of factory automation; adoption including justification, implementation, and post-implementation evaluation of AMT (Paul and Suresh, 1991). Companies are faced with many problems during these three stages. Firstly, identifying the reasons for adopting AMT and its justification. These include choosing from the various available technologies thus enabling the company to become more competitive in the market-place, and the specific justification techniques to be used to influence management in adopting AMT. Secondly, during the implementation stage, many problems may arise ranging from those concerned with the education and training of the workforce to any external assistance required. Finally, during the evaluation stage, there are various problems associated with identifying and measuring factors responsible for successful AMT implementation.

Managers have limited experience with AMT and few guidelines available to assist them in transition from the factory of today to the factory of the future (Ross, 1991; and Besant, 1994). The present study provides an in-depth integrative approach to addressing the key issues in adoption, implementation, and evaluation of AMT by focusing on the experiences of thirty-five business organisations pursuing a strategy of automation.

## 1.2 CHANGING TRENDS IN MANUFACTURING

Growing concern about the ability of manufacturers to compete in global markets has raised interest in manufacturing strategy and technological innovations in manufacturing as being possible options offering real long-term benefits. Several trends have changed the nature of competition and the manufacturing environment.

The first major change has been an increase in competition. Until the last few decades, the U.S. and European market-place has been almost exclusively dominated by domestic manufacturers. However, the entry of



foreign-made products into these markets has placed tremendous pressure on U.S. and European manufacturers (Currie, 1993). Foreign-made goods typically meet or exceed local products in terms of quality, performance, and style. In addition, foreign competitors are often able to produce exceptional products at lower costs due to advantages in wage rates, energy or raw materials. U.S. and European manufacturers are struggling to maintain market share as they are faced with this increased global competition.

With the availability and sophistication of a wide variety of foreign-made products, the consumer is also changing. Consumers are increasingly demanding unique, innovative products, delivered on a timely and reliable schedule. In addition, high quality and low price are taken for granted by these sophisticated consumers. In the face of these pressures, U.S. and European manufacturers are focusing on quality improvement programmes as foreign competitors invade their markets.

The trend toward shorter product life cycles, coupled with shrinking product development cycles are forcing manufacturers to consider changes in their traditional methods. Goldhar, (1994) describes the move to shorter product life cycles:

...Within the culture of a particular business we are seeing product life cycles shrinking to anywhere from one-half to one-third of their former lengths. Add to this much greater product variety and choice in the market .. mostly driven by the internationalisation of markets.

In addition, there is considerable pressure to decrease time-to-market for a new product. Product development cycles are changing from years to months. There is also less time to recover the investment required for these new products as the product life cycle shrinks. In light of these changes, flexibility has become a necessity for manufacturers (Kaplan and Jaikumar, 1993).

Constant shifts in global markets, product and manufacturing technologies, the positions of competitors, and the long term objectives of firms demand that restructuring be a continuous process. The evidence is overwhelming that manufacturers need to make changes in order to compete in global markets (Bandrowski, 1991). As the debate continues about possible solutions to these problems, one theme consistently emerges. For survival, manufacturing companies need: (1) to recognise that change is required, (2) to develop and implement a manufacturing strategy, and (3) to adopt new

process technology (Skinner, 1986). Adoption and implementation of advanced manufacturing technology (AMT) offer the promise of successfully competing in global markets.

### 1.3 ADVANCED MANUFACTURING TECHNOLOGY

Advanced manufacturing technology (AMT) is the generic term given to a range of systems which have been developed in recent years and have dramatically changed manufacturing processes and the design interface for many companies. Though the picture is endlessly changing, we can summarise some of these developments in ways which show their likely impact on operational strategy in a manufacturing enterprise.

AMT includes a wide variety of tools and techniques which supports world class manufacturing (Gunn, 1987). The adoption of these tools and techniques provides the scope of an integrated manufacture which involves the elimination of barriers between stages, functions, and goals of production to create a streamlined value added system (Snell and Dean, 1992). Figure 1.1 illustrates the general framework that may be used in deciding whether to adopt AMT. The procedure to introduce AMT can be categorised into three main stages: (1) the recognition of the need to improve business performance, (2) to understand the need to improve operating performance, and (3) selection of appropriate AMT (Paul and Suresh, 1990).

These technologies are complex, consisting of an integrated system of equipment, people, computers and communication networks. The potential benefits of these technologies are phenomenal. These advances hold the promise for significant improvement in everything ranging from quality, quantity, cost, flexibility, delivery, to speed, design and accuracy. These available technologies provide added freedom and gear an organisation to tighten integration of product, design, market, engineering and overall plant control.

The motivation to adopt a new technology often comes from the need for improvement of manufacturing operations. A firm should, at the very outset, explore available new technologies and how these can best fit into the functioning and consequent improvement of its overall manufacturing ideology. Since these technologies are widespread in their areas of

application, they can best be classified into three areas: design engineering; manufacturing; and production planning and control techniques, as shown in Table 1.1 (Paul and Suresh, 1991). This classification provides a means of close scrutiny of capabilities of these technologies, thus enabling a firm to determine the need for employing one or more of these technologies to satisfy manufacturing requirements.

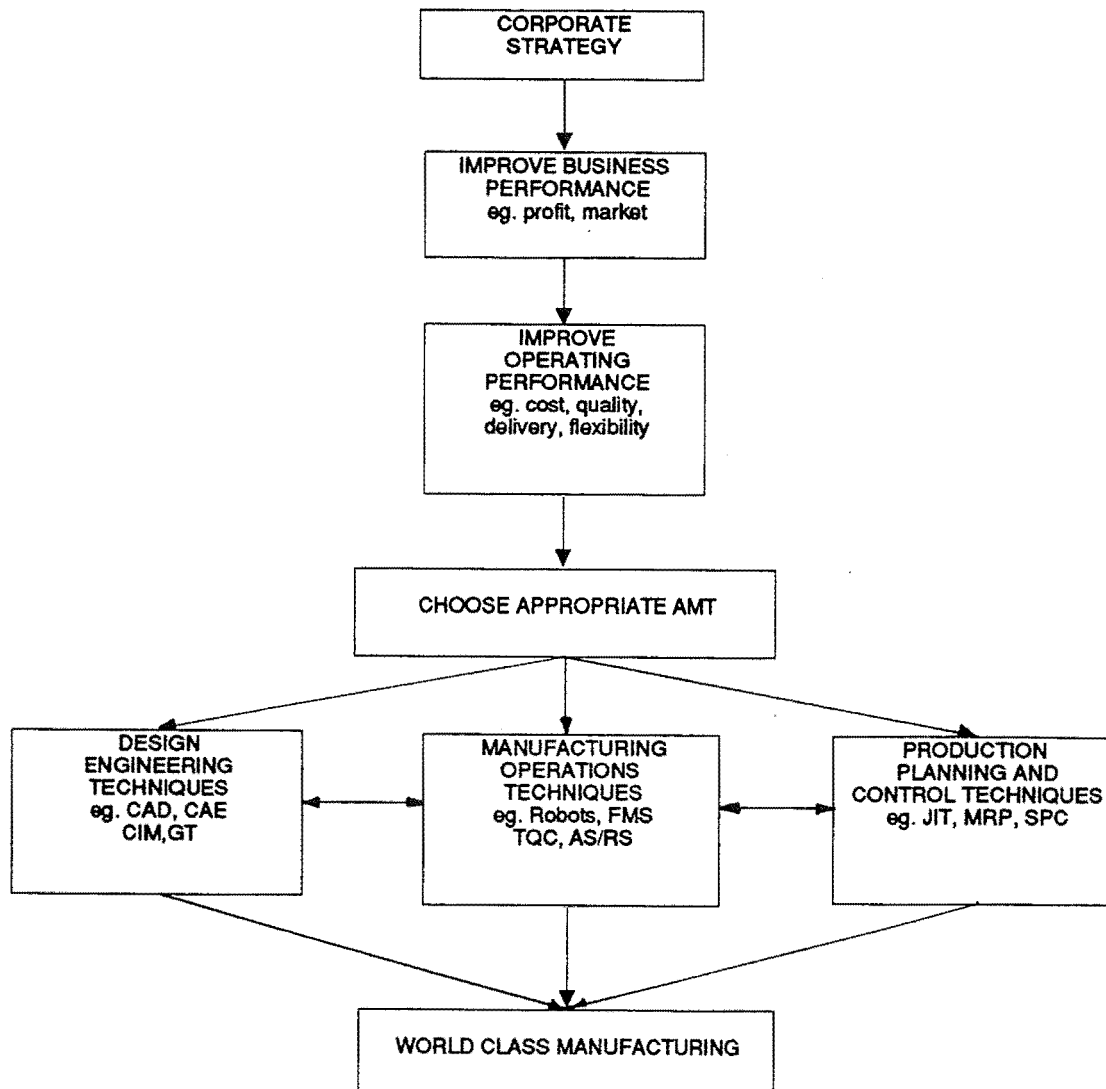


FIGURE 1.1 FRAMEWORK FOR ADOPTING AMT TO IMPROVE BUSINESS  
Source: Paul and Suresh, 1990.

Each of these new technologies offer a number of advantages. For example, numerical control (NC) and computer numerical control (CNC) equipment, although more expensive than traditional equipment, offer a number of advantages: machining flexibility, consistent quality, and reduction in skilled labour required to operate them. Similarly, robots typically improve flexibility and product quality, reduce labour requirements, and enhance safety in

hazardous working environments. Flexible manufacturing systems (FMS), comprising a collection of robots, CNC machines, and material handling devices, enhance flexibility by their ability to produce a variety of different products with improved precision at lower cost than conventional methods. Computer-aided design (CAD) systems enhance the quality and reduce the required lead time of new products. Computer integrated manufacturing (CIM) represents the integration of many or all of the elements of AMT. However, since the introduction of the concept by Harrington in 1973, many definitions of CIM have been developed (Boaden and Dale, 1986 and 1987). As a result, there is a great deal of confusion about the definition of CIM.

CIM is difficult to define. It has been variously described as "a philosophy", "a way of life," and "a journey, not a destination."...It is not a particular machine or a piece of software, nor even a particular combination of such elements. CIM is born of the recognition that...truly substantial benefits will be realised only when these devices and systems are integrated into a coherent system (Dean, 1987).

TABLE 1.1  
CLASSIFICATION OF AMT

Design Engineering Techniques	Manufacturing Operations Techniques	Production Planning and Control Techniques
Computer Aided Design	Numerical Control	Zero Inventory
Computer Aided Engineering	Computer Aided Manufacturing	Manufacturing Requirements Planning
Group Technology	Total Quality Control	Just In Time
Computer Integrated Manufacturing	Cellular Manufacturing	Kanban
	Robots	Statistical Process Control
	Computer Numerical Control	Kaizen
	Flexible Manufacturing System	
	Automated Storage/ Retrieval System	
	Automated Guided Vehicle	

Source: Paul and Suresh, 1991.

In the decision to adopt AMT a scrutiny of available technologies and their benefits is essential. In the case of an automobile ancillary manufacturer participating in this study, to gain market share the firm had to produce high quality products. Its existing machinery could not produce to the close tolerances required by the automobile assemblers. The firm's only means of survival was to adopt automation, which included design engineering and manufacturing operation techniques, such as CAD and robots. With these in place, they could not only improve their quality but also increase quantity with the option for a wider range of products, due to the flexibility of the installed systems and machines. In another case of a chemical manufacturer, the firm had to improve its manufacturing performance without much capital investment, as well as retaining its present infrastructure in which it had invested huge amounts twenty years previously. Hence, the introduction of robots and FMS was not found to be cost effective. The firm emphasised on the "soft" side of advanced manufacturing technology, its manufacturing planning and control technique. The firm decided to put in place JIT between workstations when possible, and total quality control (TQC) and statistical process control (SPC) systems were introduced. This strategy was designed to be easily implemented without much capital investment and to be capable of gradual improvement. This provided the firm a short-term solution as well as a long-term perspective for growth.

The potential offered by advanced manufacturing technologies to deal with the emerging challenges of the competitive environment of the 1990s is widely recognised. But concern has also been expressed about the ability of firms to exploit this to the fullest (Bessant, 1993). Based on the above discussion, there are two major concerns. First, US. and European manufacturers have been slow to adopt advanced process technology. Second, those firms that have decided to adopt these new technologies have had limited success in their implementation.

#### 1.4 ISSUES IN ADOPTION, IMPLEMENTATION AND EVALUATION OF AMT

If widespread use of AMT is critical for manufacturers to regain their competitive position, then there is a need for a clear understanding of the complex processes required to achieve success. Management has limited experience with these new technologies and few available guidelines to assist them in the transition from conventional manufacturing methods to automated technologies.

Given the fact that these technologies are relatively complex, it is not surprising that the number of theoretical and empirical studies of their adoption, implementation, and evaluation are limited. The available information typically focuses only on a subset of the critical issues which need to be examined and is scattered across multiple disciplines. In-depth, integrative studies, which focus on the experiences of organisations pursuing a strategy of automation, are needed.

First, research is needed to explore the reasons why firms choose to adopt AMT and the decision-making process involved. While proposing factory automation, all benefits that can be realised from AMT are proposed to top management for approval. These would range from reduction in direct labour and cycle time to safer working environment and better customer image. It has been proposed that economic justification of AMT is one of the greatest barriers to the realisation of the factory of the future (Motteram and Sizer, 1992). One of the reasons for this is the high risk associated with massive automation projects spanning many years. With high capital investments and long gestation periods for implementing these projects it becomes difficult to identify quantifiable benefits in the short term. Various financial techniques are used to justify these AMT projects, but such techniques and analysis sometimes fail to identify the longer-term intangible benefits. Hence, the obstacles to adoption and justification encountered by organisations in the process of automation need to be investigated.

Second, once these new technologies are adopted, what action plans should be developed in order to successfully manage and implement them? Purchase of AMT does not guarantee success. Implementation is an extremely complex process, frequently requiring changes in virtually all areas of the organisation. These may include changes in management practices, information technology, manpower allocation and training. The actual process of implementing AMT may involve a project team drawn from cross-functional disciplines across the organisation. The team may set priorities and manage the project schedule to tie in the various departments affected by the change process. A close co-ordination of the project team with vendors and suppliers of automation equipment is essential. During the installation and testing of hardware and software there could be many "start up" and "de-bugging" problems. Also, during this stage and after final implementation of AMT, a carefully planned programme to educate and train the employees affected by AMT is required. Organisational issues, such as

resistance to change to new systems and the possible reduction of head-count, may also arise during this stage. These issues should be carefully and effectively handled. It is important for managers to understand the above factors that contribute to or impede the successful implementation of AMT.

Finally, one would expect follow-up evaluations to be of primary importance to management. A detailed review of all aspects of implementation of AMT appears warranted. One of the main purposes of reviewing and controlling large capital investment projects is to compare the realised benefits with the forecasted benefits. This comparison should provide more information that would be useful to firms in reviewing and justifying similar projects in the future. Some of the follow-up evaluations may be difficult to make as the automation projects usually cover a wide area of the firm's business operation. To capture and quantify the overall benefits as a single unit for analysis can be complex. Hence, several post-implementation reviews over a longer period of time are required to assess the operational benefits of AMT. Obstacles to evaluation may also arise, due to the fact that measures of benefits were not available before the implementation process began, and therefore could not be compared with the measures of benefits attained after implementing AMT. The constant changing nature of the business also may make it infeasible to perform post-implementation evaluation.

Successful management of the processes of adoption, implementation, and evaluation of AMT are critical in achieving benefits in manufacturing performance. These processes should be considered as part of an overall manufacturing strategy process. A framework to incorporate relevant issues in these processes in the overall manufacturing strategy, and to analyse the effects of these issues on manufacturing performance is lacking.

## 1.5 ISSUES IN MANAGEMENT OF TECHNOLOGY

Management of technology is concerned with developing, exploiting and managing both product and process technologies, which are either internally developed or externally acquired. Emphasising the use of automation as a management decision concerned only with the manufacturing process is not sufficient. Critical issues in management of technology and technology's strategic role should be addressed. Management must make a commitment to a vision of how technology can add true value to all aspects of the business. To ensure support at the business strategy level, there should be

close integration of technology strategy and the functional strategy of manufacturing (Maidique and Patch, 1988; Weill, Samson and Sohal, 1991). Thus, important issues in the development and use of technology must be considered in formulating business strategy.

How a firm manages its technology also influences its business performance. Thus, it is necessary to determine the effectiveness of its management of technology. Technology also directs and conditions management's intuitive strategic responses to opportunities ("can we make a profit on this?"). Firms respond to new technological developments differently. A methodology to examine the responses of firms as related to business performance is required.

## 1.6 PURPOSE AND OBJECTIVES OF THE STUDY

The general purpose of this study is to explore the management processes of adoption, implementation, and evaluation of AMT. It builds on previous studies in the field, and offers further insights into key issues facing organisations in their efforts to manage AMT. The study investigates the experiences of some thirty-five European manufacturing firms which are considering or already utilising a variety of these automated technologies.

The objectives of this study are to address some of the specific issues reviewed in Sections 1.4 and 1.5, namely,

1. To document how participating firms manage the key issues in the processes of adoption, implementation, and evaluation of AMT, identifying
  - (a) the major benefits derived from AMT;
  - (b) the obstacles faced in justification and implementation;
  - (c) the critical success factors in implementation.
2. To identify the key management issues in development and use of technology.
3. To examine the effects of key management issues in adoption, implementation, and evaluation of AMT within an overall manufacturing strategy process on the performance measures in manufacturing.



4. To determine the effects of some proposed factors of effective management of technology on business performance.

## 1.7 PLAN OF THE STUDY

The role of advanced manufacturing technology in the changing environment of manufacturing has been introduced in this chapter. The complexities of the processes of adoption, implementation, and evaluation of AMT described above are presented in detail in Chapter 2, which contains a review of the pertinent studies, including an analysis and critique of their findings.

Chapter 3 states the research problem for this study and identifies the major questions in those areas in which further research needs to be focused. In addition, the details of the adopted methodology is presented, including a discussion of the study design, site selection, data collection methods, data development and formulation of hypotheses.

The results of the multiple case studies are presented and analysed in Chapter 4. First, an overview of the research sites and participants is presented. Then, a framework based on the three categories of adoption, implementation, and evaluation is used in organising and presenting the results. Each section in this chapter addresses the relevant research questions based on the empirical data collected from the case studies. The technological issues that play an important role in the business unit level performance are then investigated, in order to show the importance of strategic management of technology.

Chapter Five presents the results of the quantitative analyses. Reliability and validity of all the measurement scales used are first examined. Then the empirical relationships of the effects of AMT in manufacturing, and between the proposed manufacturing strategy framework and manufacturing performance, are presented and tested. A methodology for assessing the role of effective management of technology in the overall business performance of the firm is also presented in this chapter.

Conclusions stemming from the research and a number of suggested future research tasks are presented in Chapter 6, and a best practice model for AMT management is outlined in Chapter 7.

## 1.8 CONCLUDING SUMMARY

Background information on the changing trends in manufacturing and the need for automation to remain competitive has been reviewed in this chapter. An overview of advanced manufacturing technology, its use and capabilities has also been presented. A discussion on the adoption, implementation, and evaluation of AMT has identified the relevant key issues that need to be carefully considered by a firm embarking on a strategy of automation. Finally, the general purpose and specific objectives of this research study have been outlined.

## **CHAPTER 2**

### **REVIEW OF THE LITERATURE**

#### **2.1 INTRODUCTION**

This chapter reviews the studies pertinent to AMT, analyses and critically reviews their findings, and identifies areas which remain to be explored. In general the studies to date are scattered across multiple disciplines, including information systems, production and operations management, industrial engineering, management science, operations research, finance, accounting, and management practice. In this study a general framework, groups the issues into three broad categories: adoption, implementation, and evaluation, in order to organise the existing literature. This framework was adopted to provide a vehicle for analysing and synthesising studies across the diverse fields, and to furnish a basis for documenting how firms actually set about adopting, implementing, and evaluating AMT as a guide to management decision making.

The first section, which focuses on the decision-making process to adopt AMT, consists of two parts: strategy and justification. In the second section, the studies related to the implementation of planned changes are reviewed. The implementation literature has followed three major areas of inquiry: cognitive style, critical success factors, and process models, and studies in each of these areas are reviewed. In the third section, issues related to the evaluation process are examined. The post-implementation evaluation process of AMT has received little attention to date and therefore studies specifically addressing evaluation of AMT are rare.

#### **2.2 ADOPTION**

As indicated earlier, the threat of foreign competition is forcing U.S. and European manufacturing firms to re-evaluate their current mode of operation. The profitability or even survival of some of these manufacturers has been jeopardised. As a result, attention has focused on improving competitive ability by implementing state-of-the art technology. Advanced manufacturing

technologies offer tremendous potential to manufacturing firms. However, relatively few of them have chosen to adopt these new technologies.

The following sections examine the reasons why firms have chosen to adopt AMT and the decision making process involved. First, manufacturing and technology strategies associated with AMT are explored. Then the justification process and proposed alternative methods of justification are reviewed, and empirical studies are considered, when available. As noted in Chapter 1, the technologies that comprise AMT may be regarded innovations, specifically technological innovations. Therefore, the process of adoption of AMT may be viewed from the more general perspective of innovation literature, where there has been a substantial amount of research. While it is beyond the scope of this study to review the extensive literature in this field, a number of such studies are discussed, when appropriate.

#### 2.2.1 Strategy

The importance of manufacturing strategy to the overall success of the corporation has received considerable attention. Since Skinner published his landmark article, "Manufacturing .. Missing Link in Corporate Strategy" in 1969, (Skinner, 1985) numerous articles have been written focusing on manufacturing strategy (Wheelwright, 1984a and 1984b; Skinner, 1978 and 1985; Buffa, 1984; Hayes and Wheelwright, 1984; Schroeder, 1986; Gunn, 1987; Samson, 1991; and Hill, 1993). Manufacturing process technology, in particular computer integrated manufacturing, has been identified as a key element of manufacturing strategy. Maidique and Patch, (1978) argue that technology is, together with manufacturing, a "missing link" in corporate strategy.

In spite of many articles and books written about the subject, there has been very little empirical research on manufacturing strategy and, specifically, on the role AMT plays in strategy. Therefore, in this study the general concepts of manufacturing and technology strategy are discussed and relevant research studies, when available, are also reviewed.

### 2.2.1.1 Manufacturing Strategy

The word "strategy" is derived from the Greek military term *strategos*, meaning "the general's art". According to Wheelwright (1984a), the word has been so overused that it has lost its unique meaning. However, most definitions of strategy have a number of common characteristics.

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TABLE 2.1  
CHARACTERISTICS OF STRATEGY

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#### TIME HORIZON

Strategy is used to describe activities that involve a long-term horizon, both with regard to the time to accomplish such activities and the time it takes to observe their impact.

#### IMPACT

Although the consequences of pursuing a given strategy may not become apparent for a long time, their eventual impact will be significant.

#### CONCENTRATION OF EFFORT

An effective strategy usually requires concentrating one's activity, effort, or attention on a fairly narrow range of pursuits. Focusing on these chosen activities implicitly reduces the resources available for other activities.

#### PATTERN OF DECISIONS

Although some companies need to make only a few major decisions in order to implement their chosen strategy, most strategies require that a series of certain types of decisions be made over time. These decisions must be supportive of one another, in that they follow a consistent pattern.

#### PERVASIVENESS

A strategy embraces a wide spectrum of activities ranging from resource allocation process to day-to-day operations. In addition, the need for consistency over time in these activities requires that all levels of an organisation act, almost instinctively, in ways that reinforce the strategy.

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Source: Hayes and Wheelwright, 1984.

Skinner (1985 and 1986) defines manufacturing strategy as the achievement of congruence between manufacturing decisions and business strategy. He argues that manufacturing should articulate a primary task derived from the business strategy, and then ensure that all manufacturing decisions are supportive of this task. Hayes and Wheelwright (1984) describe five typical characteristics of strategy as listed in Table 2.1.

Table 2.2 illustrates three levels of strategy: corporate, business and functional. Manufacturing strategy fits within the third level, functional strategy. Other examples of functional strategies might include research and development, marketing and sales, and accounting control strategies (Wheelwright, 1984b). Therefore, in any particular organisation, the functional strategies must be compatible and integrated with each other in order to effectively support the competitive advantage selected at the business strategy level.

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TABLE 2.2  
LEVELS OF STRATEGY

---

**CORPORATE STRATEGY**

1. Selecting the business in which the firm will/and will not participate.
2. Acquiring and allocating resources among the selected businesses to create value for the firm's publics (constituencies).

**BUSINESS STRATEGY**

1. Clarifying the boundaries of the business to be served.
2. Selecting the desired competitive advantage to be pursued.

**FUNCTIONAL STRATEGY**

1. Determining the bases on which the function will support the desired competitive advantage.
  2. Integrating and coordinating the function with other functions to which it interfaces.
- 

Source: Wheelwright, 1984b.

Schroeder, Anderson and Cleveland, (1986) define manufacturing strategy in terms consistent with the strategic management model of Hofer and Schendel, (1979). A complete plan for the manufacturing function is formulated, which is then followed as it is implemented. This plan consists of mission, objectives, strategies and distinctive competence. Here the definition stresses the planning and implementation aspects of manufacturing strategy.

The Manufacturing Futures Project (Miller and Roth, 1987) defines manufacturing strategy:

... in terms of the choices that a manufacturing firm makes with respect to its facilities, production processes, workforce, organisation, degree of vertical integration, methods of quality control and production.

This definition corresponds to the eight decision categories comprising a manufacturing strategy: capacity, facilities, technology, vertical integration, workforce, quality, production planning/materials control, and organisation (Wheelwright, 1984a; Hayes and Wheelwright, 1984).

Gunn (1987) updates these "classical manufacturing strategy factors" with what he calls "today's manufacturing strategy objectives", as listed in Table 2.3.

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TABLE 2.3  
MANUFACTURING STRATEGY OBJECTIVES

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Shorter new-product lead times  
More inventory turnovers  
Shorter manufacturing lead time  
Highest quality  
More flexibility  
Better customer service  
Less waste  
Higher return on assets

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Source: Gunn, 1987.

Gunn's strategy objectives coincide with the expected benefits of implementing automated manufacturing technologies. Gunn stresses that Just In Time, Total Quality Control and Computer Integrated Manufacturing are tools to accomplish the companies' strategic objectives. However, the notion that one approach works for all organisations has been criticised by Wheelwright (1984a):

Since the strategy for every business has unique characteristics and aspects, its functional manufacturing strategy should also be different. Even in firms where several business employ similar or "generic" business strategies, differences will arise that require corresponding differences in the manufacturing strategy.

The above criticism was also supported by Skinner (1988).

Hill (1993) argues that manufacturing strategy should define a specific production process which is congruent with the market requirements. Hill shows how to link decisions made in manufacturing with the business and marketing strategies.

The above definitions provide a basis for specifying a framework of the manufacturing strategy process. According to the definitions, every

organisation will employ a variety of manufacturing strategies to accomplish its particular business objective. These strategies should include formal planning, they should help improve consistency of decision making and result in promoting competitive advantage.

#### 2.2.1.2 Technology Strategy

Technology strategy emphasises the importance of new technology to the firm and its contribution to overall business strategy (Martinez Sanchez, 1991). Maidique and Patch (1978) differentiate between technological strategy and manufacturing strategy.

...While the two are closely intertwined elements of business strategy, they, nevertheless, address distinct sets of decisions. Manufacturing policy principally involves decisions regarding the location, scale and organisation of productive resources. As such it is formulated within bounds of a given technology.

Technological policy, on the other hand, involves choices between alternative new technologies, the criteria by which they are embodied into new products and processes and the deployment of resources that will allow their successful implementation.

Abernathy (1978) suggested that the manufacturing process could be a serious hindrance in the process of technological renewal. He used the term "productivity dilemma" to indicate that the efficiency of the production process, associated with mature technology, could become a major obstacle for the company to internalise new technology. He was in favour of retaining the efficiency of old production systems rather than moving to the flexibility and uncertainty of production systems associated with new technologies. However, this view does not conform well to the realities of the environment of the 1990s, where firms have to operate in a manufacturing system under a large variety of constraints and uncertainties.

Hayes and Wheelright (1979) provide a framework to link manufacturing process and product life cycles. They recognised the dynamic nature of the production process noting that "just as the product and market pass through a series of major stages, so does the production process used in the manufacture of that product". Their traditional product-process classification is also losing its utility. For example, today FMS can share some of the characteristics of job shop and continuous flow environment.



Hayes, Wheelwright and Clark (1988) also argue that "a company can improve its development effectiveness only about as fast as it improves its manufacturing capabilities." They see a close link not only between product and process, but between more generic design and manufacturing capabilities.

Ford (1988) defines technology strategy for a firm as "what it knows and what it can do, rather than the products that it has or the market it serves". This consist of acquiring and managing knowledge, and the ability to exploit this for profit. Ford states that technology is not necessarily developed through in-house R&D efforts, but can also be "bought" from outside companies.

Morone (1989) postulates that firms that make strategic use of technology tend to be focused in terms of their process technologies and product families and with respect to the market in which they operate. Firms which successfully exploit opportunities in technologies are those with strong internally developed technological capabilities and those having longer time horizons than other firms in defining or representing their strategic intent.

Pappas (1984) asserts that technology considerations will form the basis for virtually all major decisions that management will make in the future. Flores and Whybark (1989) point out that the management of the new technology for manufacturing firms is a challenging, essential activity. They outline eight areas in which decisions are needed to effectively carry out a technology strategy and these are: product design, process design, plant and facility configuration, control systems, personnel programmes, research and development, purchasing, and organisation. They propose a technology-capability matrix that can be used to find the right match between the strategic needs of a company and the available array of manufacturing technologies, while considering the organisation's capabilities.

Although manufacturing strategy is a functional strategy, it can be argued that technology strategy cuts across functional boundaries, such as manufacturing, marketing, finance, and R&D. As a result, careful integration of technological strategy and functional strategies is vital to ensure support for decisions made at the business strategy level.

Technological choices are also business choices, and organisations should be willing to consider new ideas and practices, such as AMT. The next

section discusses the role AMT plays in manufacturing and technology strategy and the apparent unwillingness of managers to embrace this new technology.

#### 2.2.1.3 AMT: A Competitive Weapon

The notion of AMT as a potent competitive weapon is continually gaining support (Cardone, 1993). Skinner (1984), concurring with Pappas (1984), discusses this idea.

The potential of aggressive innovation in operations equipment and process technology is frequently a blind spot in strategic management. This powerful competitive weapon is generally unused, neglected in both corporate operations and the professional literature.

Skinner offers three reasons why U.S. manufacturers have been slow to adopt these advanced manufacturing technologies: (1) Operations continue to be measured mainly by short-term, financially oriented standards; (2) Top management has incorrectly focused on "productivity" instead of focusing on strategic objectives; and (3) Operations managers need to shift from a tactical to strategic, long-range focus. Skinner proposes that management re-adjust their focus and consider the enormous potential of new process technology. Skinner also suggests that implementation of automated technologies will result in a "factory with a whole set of economics." According to Skinner (1984), the expected changes are significant.

Changes in these factors may produce an order-of-magnitude change in the factory. It is not exaggeration to say that the factory is being reinvented in the '80s.

Cohen and Zysman (1988) share the view of Skinner and Pappas and assert that U.S. manufacturers have been slow to adopt or adapt to the emerging technological innovations. They also view operations as a powerful competitive weapon.

The important outcome is that the relation between production and corporate strategy is altered. Manufacturing becomes a competitive weapon... Dynamic flexibility, in contrast to static flexibility, means the ability to increase productivity through improvements in production process and product innovation... In a period when technologies permit new production strategies, dynamic flexibility is crucial.

Hass (1987), also a supporter of exploiting the power of manufacturing as a competitive weapon, stresses the importance of technology and particularly, automated manufacturing technologies.

Technology's dramatic transformation of the factory has strengthened the link between manufacturing strategy and business strategy and thereby invalidated a host of time-tested operational principles and decision criteria. More and more, competitive advantage will go to the companies that seek strategic breakpoints through the integration of decisions in every area of manufacturing.

This connection between manufacturing and technology strategy is reinforced by others (Kantrow, 1980; Goldhar and Jelinek, 1983; Jelinek and Goldhar, 1984; and Blois, 1986). The strategic advantages of AMT for small firms is highlighted by Meredith (1987a). Goldhar (1986) takes the argument a step further and asserts that:

In the Factory of the Future, innovation is productivity, and is the only way to compete in the evolving global marketplace for both consumer and industrial goods.

In summary, it appears that management must consider the impact of AMT on the overall business strategy. A well-defined, clearly articulated business strategy, with a long-range focus, incorporating both manufacturing and technology strategies, is the key to successfully adopting and implementing AMT. This study addresses the issues in linking a manufacturing strategy process using AMT with manufacturing performance and factors of effective management of technology with business performance of the firm.

#### 2.2.1.4 Empirical Studies

While a great deal of work has been published in stressing the importance of AMT and manufacturing strategy in formulating overall corporate strategy, there are only a few empirical studies in this area cited in the literature.

Schroeder, Anderson and Cleveland (1986), performed an exploratory study based on data from thirty-nine companies. Specifically, the study focuses on the content of manufacturing strategy, which they define as "the type of strategies used, the way they are defined, the linkage with business strategies and ultimately whether they help the business gain a competitive advantage."

The researchers used a questionnaire with both open-ended and close-ended questions. The questionnaire was administered to manufacturing managers enrolled in an executive programme on manufacturing strategy. The companies in the sample represented a wide range of size and

industries. However, approximately 75 per cent of the sample consisted of small and medium-sized companies. The main purpose of their study was to gain an understanding of manufacturing strategy.

The authors report that the business strategies of the sampled firms were "growth oriented, market directed and emphasised quality and service." The major conclusion of the study is that progress is being made in articulating manufacturing strategy and its strong link with business strategies. The authors conclude:

...manufacturing is a significant competitive force in many of these companies and not as reactive as the literature would suggest. Manufacturing strategy does appear to follow from business strategy and is consistent with it. However, the manufacturing's distinctive competence may not be getting the consideration it deserves in the formulation of business strategy.

The results of this study, while quite positive, may be somewhat biased because of the non-random composition of the sample. The fact that this group of managers attended a programme on manufacturing strategy might indicate a more progressive and positive attitude toward manufacturing strategy.

A study by Jaikumar (1986) investigates flexible manufacturing systems to understand how they are actually being used and if they are achieving the anticipated strategic objectives. The study compares the products of 95 companies in Japan and the U.S. Jaikumar's results indicate that Japan is reaping the benefits of flexible automation, while U.S. manufacturers are using it poorly.

The average number of parts made by an FMS in U.S. was 10; in Japan the average was 93... The U.S. companies used the FMSs the wrong way - for high volume production of a few parts rather than for high-variety production of many parts at low cost per unit...Nor have U.S. installations exploited opportunities to introduce new products... U.S. is not using manufacturing technology effectively.

Jaikumar agrees with Skinner (1984), "the technology itself is not to blame; it is management that makes the difference." Although this study paints a gloomy picture for U.S. manufacturers implementing automated systems, the results achieved by the Japanese firms strongly support the proposed strategic, competitive advantages of factory automation. Jaikumar's concluding remarks underscore this notion:

FMS are no longer a theory, a pipe dream. They exist. And the leverage they provide on continuous process improvement is immense. Making automation work means a whole new level of process mastery.

Darrow (1987) compares 253 manufacturing facilities using FMS across four geographic regions: Eastern Europe, Western Europe, Japan and United States. Although this study does not specifically address the strategic issues, it demonstrates that "rapid exponential growth" of FMS technology was occurring in all regions except Eastern Europe. In terms of the number of firms with experience in automating, the U.S. lags behind both Western Europe and Japan. Darrow notes the growing challenge to scholars and practitioners, who need to develop techniques to deal with these rapidly emerging technologies.

A few other research studies touch on strategic issues (Slack, 1987; Lim, 1987; and Meredith, 1987 and 1993). For example, Slack studies ten manufacturing organisations, using informal interviews, to gain an understanding of managers' views on manufacturing flexibility. In addition, he presents an hierarchical framework for conceptualising and analysing the flexibility needs of manufacturing organisations. Meredith (1993), studies the use of FMS in three business units over a period of six years. The results question the value of manufacturing flexibility and the other widely recognised basic competitive priorities of cost, quality, and delivery. The results also indicate that the operating characteristics of technologies tend to be independent of the original business strategy and that manufacturing technology strategy is highly dynamic.

Another study by Schroeder, Congden and Gopinath (1988), explores the linkages between competitive business strategies and the level of process technology sophistication of twenty small to medium-sized manufacturers. This study used semi-structured interviews and plant tours to collect data from the organisations studied. The researchers conclude that a close alignment between strategy and technology is advantageous. However, "the process by which this is made may have a significant impact on the extent to which it can actually be used to create a competitive edge."

The most extensive study to date has been performed by the Manufacturing Futures Project by Miller and Roth (1984, 1985, 1986, 1987, 1990, 1991, 1992). This survey analyses the manufacturing strategies that firms plan to employ in the future. It was initially developed in 1982 and administered to

160 top manufacturing executives in the U.S. and Canada, is now administered to over 600 executives in the U.S. Canada, Japan and Europe. Miller and Roth (1987) note that manufacturing is undergoing a "significant metamorphosis."

The most radical changes are being planned for the infrastructure and process technology for these businesses... Changes expected in information systems and process technologies, strongly imply that the successful manufacturing manager in the future must be first and foremost a facilitator, an implementor, and an integrator.

The results also indicate that 62 per cent of the respondents increased investments in technology, although investments in automation differ substantially by industry.

From this study of Miller and Roth (1987), three strategies emerge: a service value strategy, a product value strategy and an innovation strategy. In addition, the study confirms that action plans, strategies and goals are consistent within firms. The survey results present evidence that progress is being made in articulating manufacturing strategy and its strong link with business strategy.

Roth and Miller (1990) show that there is a strong relationship between manufacturing strategy, manufacturing strength, managerial success and business unit performance. They provide evidence of the link between the content of manufacturing strategy and performance criteria, using the Hayes and Wheelwright (1984) conceptual framework. They define manufacturing strategy content in terms of structural and infrastructural decisions, and define manufacturing performance in terms of quality, delivery, flexibility, price and market scope.

In summary, the importance of manufacturing strategy and technology strategy in the overall success of the corporation is gaining ground. In addition AMT is expected to play an increasing role in gaining competitive advantage. There are many issues that need to be addressed with respect to manufacturing strategy and technology strategy in manufacturing.

### 2.2.2 Justification

Economic justification of AMT has proven to be an extremely difficult task and some propose that it is one of the greatest barriers to the factory of the

future (Currie, 1990; and Lefley, 1994). One reason for this is the enormous risk associated with large, technologically advanced projects that extend over many years. Hard economic justification for an entire CIM project may be exceedingly difficult, if not impossible, due to the combination of excessively high costs and an inability to identify quantifiable benefits. This section investigates the issues related to economic justification of AMT.

Benefits, both tangible and intangible, and potential risks and costs related to the adoption and implementation of AMT are discussed below. Existing economic justification techniques for AMT, often believed to be inadequate, are explored. This section also reviews some of the proposed alternative methodologies for justifying investment in automated systems. Very few empirical studies have been performed to test the commonly held beliefs regarding benefits, costs and risks associated with factory automation. Several surveys and case studies have attempted to quantify these factors (Rosenthal, 1984; Lim, 1987; Meredith, 1987b and 1987e; and Dean, 1987). However the literature is still in the exploratory stage and lacks a firm theoretical and methodological base.

#### 2.2.2.1 Benefits, Risks and Costs

As discussed earlier, AMT is being billed as the "competitive weapon" in the struggle for productivity improvements and success in global markets. The benefits of AMT have received wide publicity in public and trade presses. Penning (1987) and Meredith (1987a) highlight some of the benefits typically believed to be associated with the factory of the future (Table 2.4).

It has been suggested that many benefits result from integrating the functional areas of the firm and integrating the automated systems used to support these functional areas (Goldhar and Jelinek, 1985).

The computer allows us to integrate not only the factory itself, but also to integrate manufacturing with such functions as engineering and marketing, at a level never before possible... In short, computer integrated manufacturing shifts the factory from economy of scale to an economy of scope.

In a traditional manufacturing setting, economies of scale have been realised from producing large volumes with limited variety. Automated technologies offer economies of scope, where firms move away from mass production of a limited range of products to low cost production of a variety

of products. As a result, manufacturing organisations should be more responsive to shifts in market demand.

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TABLE 2.4  
PROPOSED BENEFITS OF FACTORY AUTOMATION

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TANGIBLE

- Higher profits
- Less direct labour
- Increased machine utilisation
- Reduced scrap and rework
- Increased factory capacity
- Reduced inventory
- Shortened new product development time
- Fewer missed delivery dates
- Decreased warranty costs
- Reduced floor space
- Decreased cycle time

INTANGIBLE

- Higher employee morale
- Safer working environment
- Improved customer image
- Greater scheduling flexibility
- Greater ease in recruiting new employees
- Increased job security
- More opportunity for upgrading skills

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Source: Penning, 1987 and Meredith, 1987a.

Meredith (1987e) studied several cases of firms implementing flexible manufacturing systems and found some unanticipated benefits from the technology.

One of the biggest benefits they received from the FMS, one totally unexpected, was its action as a catalyst for change. The FMS forced the managers to re-examine the way they ran the rest of the plant. After seeing the benefits that arose from interfacing areas affected by FMS, they instituted similar improvements in other areas of the plant and realised significant additional benefits.

The tangible and intangible benefits noted above are not without risk. There is substantial risk associated with the acquisition and implementation of automated manufacturing technologies. These advanced technologies are extremely expensive systems, ranging from approximately U.S. \$3 to U.S. \$10 million for a flexible manufacturing system, which is one element of factory automation. The stakes are high, given the poor track record of successfully implemented systems, to date. Anticipated benefits may be only



partly realised as new technologies sit unused. The firm may find itself in serious trouble as it struggles to meet production schedules, to provide timely customer delivery and to ensure a high level of product quality.

In addition to the financial risk, implementation of AMT introduces organisational risk. Implementation of AMT challenges the existing infrastructure of an organisation (Meredith, 1986b).

...the entire company infrastructure must often be changed to obtain the benefits these systems offer. Consistent quality of input materials, new costing and payroll systems, and altered managerial structures are only a few of the many changes in the core fabric of the firm that are commonly required.

The organisational risks are difficult to identify and quantify; as a result, they are often overlooked in the justification process. Some of the costs associated with factory automation include, for example equipment and hardware expense, software expense, site preparation, training of operators and maintenance personnel, education for all employees and the development of new operating procedures.

As noted above, the investment in hardware represents a significant expense for the organisation implementing factory automation. Hardware and equipment costs will vary depending upon existing computerisation and extent of automation expected. Establishing an assortment of mainframes, minicomputers, programmable controllers, peripherals (such as printers, bar code recorders, voice recognition systems and communication devices) results in very costly system.

Like hardware, software is a major expense and is often underestimated during the planning phase. Not only must the firm acquire commercially developed software and/or custom-developed software, but ongoing programming, debugging and prototype development costs may be incurred. Interfacing the various elements of the automated systems is a particularly challenging aspect of software development, and incompatibility may lead to significantly increased software costs.

According to the research by Hayes and Clark (1985 and 1986), serious temporary declines in productivity may typically accompany the introduction of new process technology. Kaplan (1986) also notes:

These productivity declines can last up to a year, even longer when a radical new technology like CIM is installed... Far from achieving anticipated savings,

the post audit will undoubtedly reveal lower output and higher costs than predicted.

Therefore, the firm might incur costs associated with lower productivity for some period of time.

Due to the fact that AMT is relatively new and experience with its implementation has been limited, the associated benefits, risks, and costs are blurred. Research is needed to pinpoint more accurately what to expect in these areas by studying organisations engaged in the implementation of AMT.

#### 2.2.2.2 Justification Techniques

Attempts to justify investments in computer integrated manufacturing systems have resulted in frustration with traditional discounted cash flow financial justification methodologies. Many have viewed these approaches inadequate and inappropriate in justifying investments in factory automation. Gold (1982) was one of the first to subscribe to this belief.

The real promise of CAM technology lies not in its use as yet another, perhaps fancier than usual, machine tool located at a single point in an otherwise unchanged production process. CAM's promise lies by contrast, in its ability to integrate adjacent operations with each other and with overall control systems. Because it offers a systematic - not a "point" - capability, neither its purchase nor performance should be evaluated in the traditional way.

Historically, manufacturing equipment has been justified on the basis of cost reduction or capacity expansion. Some have argued that the traditional approaches are better suited for evaluation of short-term investments rather than long-term strategic programmes. In addition, when these traditional justification methodologies are coupled with high hurdle rates, proposals for automated systems are often rejected (Canada and Edwards, 1987; Canada, 1986; and Swann and O' Keefe (1991).

Hayes and Garvin (1982) also criticise the traditional technique:

Today such calculations have, because of their apparent rationality, gained the upper hand in the evaluation of new investment proposals. Yet these techniques are as subject to misconceptions and biases in application as are other, less formal methods.

Both criticisms are rebutted by Kaplan (1986), who insists that the real problem lies in improper application of the discounted cash flow technique.

When evaluating investments in AMT, managers must apply DCF approach more appropriately and be more sensitive to the realities and special attributes of CIM.

Kaplan urges management not to act on "faith alone" when making critical decision about whether to acquire CIM equipment.

Financial analyses that focus too narrowly on easily quantified savings in labour, materials or energy will miss important benefits from CIM technology. .... the challenge for managers is to improve their ability to estimate the costs and benefits of CIM, not to take the easy way out and discard the necessary discipline of financial analysis.

Kaplan has also been credited with the statement: "Accountants who assign zero values to many intangible benefits prefer being precisely wrong to vaguely correct..." So, the controversy rages about the most appropriate approach to follow in the economic justification of AMT.

#### 2.2.2.3 Alternative Methods of Justification

A number of articles offer guidelines to organisations contemplating investment in automated manufacturing technologies. These guidelines suggest combining discounted cash flow techniques with subjective estimates of long term costs and qualitative benefits (Bennett, 1987; Works, 1987; Muir, 1987; and Lefley, 1994). This approach is consistent with the traditional model of subjective probability distribution estimation found in capital budgeting literature (Bierman and Smidt, 1988). It is also proposed that management consider the results of these justification techniques from a broader perspective.

Keen (1981) proposes a methodology for planning and evaluating Decision Support Systems (DSS). Similar to investments in factory automation, DSS benefits are often qualitative and due to the "evolutionary" nature of these systems, costs are difficult to assess. The proposed justification methodology, value analysis, is a two stage process. This technique is particularly relevant for evaluating technical innovations, where qualitative issues are prevalent and costs and benefits are blurred.

Smith (1983) proposes four techniques for measuring the intangible benefits of computer based information systems: value analysis, incremental analysis, expected value and benefit profile. Incremental analysis and

expected value assign probabilities to estimates of projected benefits and costs, avoiding the difficulty of determining a point estimate of the benefits and costs. The benefit profile chart assigns weights to each benefit, which are then ranked on the basis of the highest weighted scores. This method does not yield dollar measures of system benefits. While these techniques offer alternatives to the typical cost-benefit approach or discounted cash flow method, they may be inadequate to assess the feasibility of implementing factory automation.

Another non-traditional method for evaluating automated manufacturing systems is proposed by Canada (1986). In this procedure, investment opportunities are separated into three categories: operational (short run), administrative (medium run) and strategic (long run). The operational decisions, usually routine, may be determined by the traditional techniques such as net present value or payback. However, the administrative and strategic decisions require a different approach. These opportunities are ranked by determining weights for each outcome or benefit associated with the investment opportunity. Within each opportunity, mutually exclusive alternatives are evaluated by: (1) assigning weights to non-monetary (intangible) factors and (2) determining net present worth for monetary (quantifiable) factors. Armed with this information, the decision maker can balance strategic and tactical factors together with financial measures, when evaluating advanced manufacturing systems.

Another alternative approach to the evaluation of robots and other advanced manufacturing systems is offered by Kulatilaka (1984). This evaluation technique considers the direct and indirect implications of installing these technologies. In addition, the technique acknowledges the fact that some benefits may be realised downstream, long after the introduction of the system. This method identifies incremental expected cash flows of the proposed project.

Table 2.5 lists various factors to be considered when calculating incremental cash flows. Kulatilaka applies the Capital Asset Pricing Model (CAPM), in order to identify a particular discount rate adjusted for the special risk characteristics of the proposed project. One would expect an increased level of systematic risk for an automation project when compared with risk levels

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TABLE 2.5  
INCREMENTAL EXPECTED CASH FLOW

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INITIAL COSTS (incurred at time 0)

Purchase of machine and equipment  
Rearrangement of plant and space savings  
Redesigning of products  
Interfacing costs  
Retaining labour and/or hiring labour with new skills  
Other installation costs

OPERATING COSTS/BENEFITS (incurred throughout life of equipment)

Labour savings  
Increased skill labour  
Material savings  
Energy, heating and lighting cost increases  
Lower inventory costs  
Revenue from increased output  
Other product and plant specific operating costs

TAX EFFECTS

Taxes on net change in operating cash flows  
Depreciation

---

Source: Kulatilaka, 1984.

of conventional production processes. To further refine the project's risk rate, sensitivity analysis is performed by varying the following parameters: costs and benefits; discount rates and inflation rates; life of the equipment; and depreciation method. Kulatilaka (1984) states:

The task facing the decision makers is to combine financial analysis with a subjective evaluation of the strategic effect, in arriving at the final decision as to whether or not to invest in a proposed project.

This approach removes some of the subjectivity and accounts for risk involved in investment decisions of advanced manufacturing technologies.

Voss (1986) challenges techniques, such as Kulatilaka's, which add risk premiums for new manufacturing technology.

Failures usually arise because of poor management of the technology not because of the technology itself... The risk of not adopting new technology usually outweigh the risks associated with new manufacturing technology. The real risks are market risks.

Contrary to Voss's belief, one could argue that firms who choose to implement new manufacturing technology are raising their fixed costs and

have a higher operating leverage. In effect, a firm with a high operating leverage is more sensitive to systematic risk. Voss cites an example of a manufacturer who "uses a normal rate of return when evaluating new manufacturing technology, but adds a risk premium if old manufacturing technology is proposed." It is suggested by Voss that firms must base their evaluations on the consequences of not adopting factory automation (decreasing market share, cost competitiveness, profitability, etc.). Voss appears to be considering the strategic implications of adopting AMT.

Meredith and Suresh (1986) propose a conceptual scheme to match the justification procedure with the intended use of the particular technology. AMT span a continuum from stand-alone equipment to fully automated systems. The level of integration and the synergistic effects increase with the movement from stand-alone technology to CIM.

The authors suggest three separate justification approaches to match the three categories of manufacturing technology namely stand-alone ( robots, NC machines), linked (GT, FMS, AS/RS) and integrated (CIM). The justification methods are: economic, analytic and strategic. For stand-alone systems traditional techniques, such as payback, return on investment, internal rate of return or net present value are suitable. But :

when synergy, flexibility, risk and non-economic benefits are expected, as with linked systems, more analytical procedures are needed... Subjective estimates of probability distributions, are at least point estimates are obtainable and can be included in the analysis... With systems approaching full integration, clear competitive advantages and major increments toward the firm's business objectives are usually being obtained. Strategic approaches are needed.

The analytical justification techniques are somewhat more complex than the economic approaches; however, they tend to be more realistic and capture uncertainty. Portfolio analysis utilises a combination of non-numeric, scoring models (similar to the technique described by Canada), and programming models (Keen, 1981). Programming models may be framed as integer formulations or goal programming formulations. Risk analysis simulates the projects under consideration and derives a frequency distribution of outcomes statistically.

The strategic approaches tend to be less quantitative than either the economic or analytic techniques, and typically involve subjective estimates of key indicators or surrogate measures related to strategic objectives. It is

common for all three methodologies to be combined to give a better assessment of the investment opportunity.

In summary, the traditional methods of economic justification have caused concern among many who are attempting to evaluate proposals for AMT. Many have argued that the traditional approaches fail to take into account the strategic implications of factory automation, including the synergistic benefits to be gained from linking automated technologies together. In response to these criticisms, practitioners and researchers have proposed alternative methodologies to cope with the nature of the benefits and the potential risks associated with AMT. It is beyond the scope of this study to explore individually the justification systems reviewed in the literature. As a more strategic approach rather than the financial justification of AMT is employed. An attempt is made to evaluate the actual process involved and the obstacles faced by firms when justifying their AMT projects.

#### 2.2.2.4 Empirical Studies

As noted above, there have been a number of theoretical articles written about alternative justification techniques, and also some research has been done on innovation and resource allocation processes. However, there is very little research on the justification process for AMT cited in the literature.

One notable exception is a study by Dean (1987) in which he provides an in-depth look at the organisational decision-making process that manufacturing firms undertake concerning the adoption of technological innovations. Using a multiple case research approach, Dean studied five organisations in five different industries in the process of making justification decisions for AMT. He used an unstructured, open-ended approach in interviewing individuals involved with the justification process.

Dean's unique contribution is that he brings together a common set of observations based on the five case studies and constructs an overall model of the justification decision process, paying particular attention to the most common barriers to innovation and how the participants overcame them.

While Dean does not offer an alternative methodology to justify AMT systems, he offers insights into this extremely complex and sometimes chaotic process. He points out that, by investigating a small number of

cases in great detail, it may be inappropriate to generalise the findings to include other types of innovations and organisations. In addition, the findings, arrived at by means of an inductive process, should be regarded as "propositions or hypotheses about the nature of the innovation decision process, subject to verification in other settings." However, in general, Dean's study represents one of the first in-depth examinations of the justification process and provides a basis for future research.

In this study, hypotheses are formulated to test the interactive effects of integrated manufacture using CIM, TQC, and JIT on performance measures: cost, quality, delivery, and flexibility.

## 2.3 IMPLEMENTATION

Once the decision has been made to adopt these new technologies and an acceptable justification has been prepared, the implementation process begins. However, contrary to the belief of many managers and engineers, the purchase of AMT does not ensure its successful use. The implementation process is extremely complex, frequently requiring changes in management methods, human resources allocation, organisational structure and design. The transition from the factory of today to the factory of the future requires major changes in virtually all areas of an organisation. Therefore, it is important for managers to understand the factors that contribute to or impede the successful implementation of AMT.

A substantial body of literature addresses the difficulty of implementing planned changes in organisations. This implementation literature has evolved since the late 1960s and encompasses many different fields including: information systems, operations research/management science, production and operations management, and general management. The literature consists of a combination of conceptual models, empirical research studies with statistically verified procedures, case studies, anecdotes, insights of consultants, and informal rules of thumb of practitioners.

The major objective of implementing any automated system is to realise the intended benefits. As the number of system interfaces increases, the complexity of the implementation increases, as well as the risk. This is certainly the case for automated manufacturing systems. Implementation



activities require significant amounts of time, energy and resources in organisations; however, it is well recognised that many automated systems are failures. As many efforts fell far short of their intended objectives, researchers have attempted to provide guidance to management regarding effective implementation factors and techniques.

Before proceeding to a discussion of the literature, it is necessary to distinguish between installation and implementation. "Installation" involves the physical placement of a system in an organisation, including a checkout of its functions to see that it is operating as designed (Meredith, 1981). The long-term nature of implementation is stressed by Lucas (1982).

...it is a part of a process that begins with the very first idea for a system and the changes it will bring. Implementation terminates when the system has been successfully integrated with the operations of the organisation.

Based on these definitions, it is quite possible to have a successful installation of an automated system, while the implementation may be classified as a failure.

The implementation literature has followed three major areas of inquiry: cognitive style, critical success factors, and process models, which are reviewed in the next three sections. Following the discussions of the major conceptual models in these three areas, some of the major studies specifically addressing implementation of AMT are reviewed.

### 2.3.1 Cognitive Style

Some of the earliest implementation literature examined the relationships between cognitive style and personality characteristics of adopters and non-adopters or managers and researchers. In particular, it was hoped that differences in cognitive styles between managers and operations researchers could provide insight into the implementation of operations research recommendation.

Huysmans (1970) in a laboratory experiment investigated the impact of cognitive style differences between management scientists and managers on the managerial implementation of recommendations. Following from earlier work in the psychology literature on cognitive style, Huysmans distinguished between analytic and heuristic "ways of reasoning." The

subjects were classified according to their tendency to use analytic reasoning or heuristic reasoning in specific decision-making situations. The experiment, a computer simulated business game, required subjects to accept and actually use an operations research proposal. Huysmans reported significant differences between the actual use or implementation of the techniques of analytical and heuristic subjects. He concluded that implementation of management science recommendations was influenced by the cognitive style of the adopting manager.

This earlier study, which may have some relevance for relatively straightforward system implementations with a single implementor, has limited applicability for the complex implementation of advanced manufacturing technologies. The adoption and implementation of AMT generally involves many individuals in a variety of functions at numerous levels of the organisation. These univariate models are not necessarily applicable to the multivariate problems encountered in the implementation of AMT.

In a more recent study, Duimering, Safayeni and Frank (1993) argue that in order to take best advantage of integrated manufacturing technologies, it is necessary to examine these systems within the organisational context. Such an examination can not only improve the design of such systems, it may also increase the likelihood of their successful implementation.

### 2.3.2 Critical Success Factors

Following another line of inquiry, researchers have attempted to identify underlying factors critical to implementation success. The purpose was to identify an important set of characteristics or factors, which might significantly improve the likelihood of successful implementation. If a casual link could be established between the independent variables, then an implementation strategy could be developed emphasising the independent variables. According to Lucas (1982):

While individual studies of implementation have addressed a number of independent variables, there is no real consensus in the field on an explanation of successful implementation or on a single implementation strategy.

Table 2.6 lists some of the independent and dependent variables used in a previous implementation study of information systems.

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TABLE 2.6  
VARIABLES ASSOCIATED WITH IMPLEMENTATION STUDIES

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INDEPENDENT VARIABLES

Information Services Department  
     Policies  
     System design practices  
     Operations policies  
 Involvement  
     User origination of systems  
     Involvement and influence  
     Appreciation  
 Situational and Personal Factors  
     Personality type  
     Business history  
     Social history  
     Structural factors  
     Past experience  
 User Attitudes  
     Expectations  
     Interpersonal relations  
 Technical Quality of Systems  
     Quality  
     Model characteristics  
 Decision Style  
     Cognitive Style  
 Management  
     Actions  
     Consultant/client relations  
     Support  
     Location of researcher  
     Managerial style  
 User Performance

DEPENDENT VARIABLES

Implementation  
     Frequency of inquiries  
     Reported use  
     Monitored frequency of use  
     User satisfaction

---

Source: Lucas, 1982.

Researchers grappling with the issue of what constitutes a successful implementation, have not agreed on an indicator of success. As identified in Table 2.6, a number of different outcome variables have been used to operationalise "successful implementation". If use of the implementation system is voluntary, then success has been measured by level of use. However, if use of the system is mandatory, the user's evaluation of the

system has been a proxy for success. User satisfaction has been evaluated in numerous other studies (Lucas, 1982).

An exploratory study performed by Harvey (1970) focuses on the acceptance and implementation by management of solutions recommended by management scientists. The objective was to identify a group of factors correlated with implementation success. The factors clustered into three groups: management characteristics; characteristics of the problem; and characteristics of the management science team and the solution.

As Harvey points out, this study has a number of limitations, including subjective judgement by the researchers in selecting the factors, lack of a random sample, and measures of subjects opinion versus actual behaviour. As a result, the generalisability of this study remains in question.

Anderson and Narasimhan (1979) address the concept of project risk assessment in order to identify the chance of success or failure of an implementation. They propose a methodology to identify the "risks of failures" so that strategies might be developed to reduce, or overcome the likelihood of unsuccessful implementation. The authors dismiss the requirement for defining "successful implementation", noting that "what is of consequence is that a workable definition exists for the management involved."

Discriminant analysis was the methodology selected by Anderson and Narasimhan for their study. The purpose was to identify a linear combination of independent variables or risk factors, which could then be used in the discriminant function to determine the discriminate score, a measure of the effect of all risk factors. This score provides the basis for classifying a given implementation as a potential success or failure. The set of risk factors are to be identified from

existing theories and models of implementation in the literature as well as additional factors that are deemed important given past experience.

Meredith (1981) surveyed the implementation literature across a number of fields: management information system, operations research/management science and production-inventory management. This exhaustive study concluded:

...previous implementation research has either been incomplete, inaccurate or insufficiently discriminating between symptoms and basic causes. By pooling results from multiple fields this study has identified what appear to be basic causes, rather than symptoms, of implementation success and failure.

The major contribution of Meredith's paper is the classification scheme developed for the basic underlying factors which might give rise to the symptoms of implementation failure. Meredith notes approximately a dozen factors which also emerge consistently in the literature. These factors are grouped in three major categories:

#### TECHNICAL

Factors which relate to the mechanics of the implementation procedure, such as adequate training, ability of the project team, accurate data and the implementation mechanics.

#### PROCESS

Factors concerned with the initiation and use of the system, such as user participation in the design of the system, the active support and involvement of top management, the role of the systems advocate and the system fit with organisational and personal goals.

#### INTER-ENVIRONMENTAL

Factors identified as the "true organisational supports" for the system, such as the real importance of the system to the organisation and the organisation's willingness to change.

The technical factors are the most straightforward and easily understood; however, the degree of complexity and abstractness increase for the process factors, while the inner-environmental factors are even less well-understood.

Geisler and Rubenstein (1987) made an empirical study to investigate the factors related to successful implementation of application software in manufacturing. They interviewed managers of 21 Fortune 200 companies who had partial or complete responsibility for production software implementation. Based on the results of the interviews, Geisler and Rubenstein grouped 21 factors in three major categories and associated these groups with steps of the implementation process. The three major categories are: factors related to the project, factors related to the organisation and its structure, and factors related to management. The factors in these categories can generally be mapped on to Meredith's earlier set of categories. Geisler and Rubenstein note that even though their

sample is insufficient statistically, it is sufficient to identify "trends, problems and the patterns of behaviour encountered in major corporations."

User involvement and participation in the implementation process has been viewed as an important success factor by practitioners and academics alike. User involvement falls within Meredith's major grouping of "process" factors.

Ives and Olson (1984) in a survey provide a comprehensive review of the empirical literature which links user involvement and indicators of system success. They highlight the problem with research, which fall into three categories: theory, measurement and methodology. Based on flaws in these areas, they conclude that empirical research has not been able to demonstrate when and what type of user involvement even contribute to system success. Drawing from reference fields, such as organisational behaviour, they offer relevant theories, including participative decision-making and planned organisational change. In addition, these frameworks provide a number of tested research methods and suggest testable hypotheses.

Zairi (1992) proposes that success in AMT implementation occurs when the set objectives and predictions carried out by the adoption strategy are fully realised. Based on the formation and close examination of various networks of relationships involving 10 suppliers and 20 users of AMT, innovation, success and failure in AMT implementation are examined. The results show that, in addition to the various internal factors applicable to the users themselves, there are other factors that tend to inhibit or facilitate the implementation process, which pertain mainly to suppliers of AMT.

The purpose of these models was to identify a single set of characteristics or factors which might significantly improve the likelihood of successful implementation. From the preceding discussion, it is clear that there is little consensus about the underlying factors critical to implementation success or on what constitutes a successful implementation.

### 2.3.3 Process Models of Change

Another stream of implementation research models system implementation as a process, consisting of distinct, sequential stages. Most of the research contributions which utilise process models draw on the framework

developed by Kolb-Froham (1970) and further extended by Lewin and Schein, cited by Srinivasan and Davis (1987). In this framework implementation is regarded as a special case of organisational change involving a three-stage process, in which behaviour is unfrozen, moved and re-frozen. The Kolb-Froham model identifies seven stages, which can be mapped on to three stages of the Lewin-Schein framework as illustrated in Table 2.7

TABLE 2.7 THE KOLB-FROHMAN AND LEWIN-SCHEIN MODELS OF CHANGE		
KOLB-FROHMAN	ACTIVITIES	LEWIN-SCHEIN
Scouting	Client and consultant assess each other's needs and abilities; entry point is chosen.	Unfreezing
Entry	Initial statement of problem, goals and objectives; develop mutual commitment and trust; establish need for change.	Unfreezing
Diagnosis	Gather data to define clients problems and goals; assess available resources.	Unfreezing
Planning	Define specific operational objectives; examine alternative routes to those objectives and their impact on the organisation; develop action plan.	Moving
Action	Put the best alternative solution into practice; modify action plan if unanticipated consequences occur.	Moving
Evaluation	Assess how well objectives were met and decide to evolve or terminate.	Moving and Refreezing
Termination	Confirm new behaviour patterns; complete transfer of system ownership and responsibility to the client.	Refreezing

Source: Lewin-Schein as cited by Srinivasan and Davis, 1987.

Extrapolating from this model, Alter and Ginzberg (1978) hypothesise that success in implementation is positively correlated with the quality of the implementation process. They developed a questionnaire to measure the relation of success or failure of the implementation effort in each of the

specific stages of the Kolb-Frohman model. Data collected in a survey of 29 computer-based systems indicated that successful projects tend to confirm more to the model's seven stages than do unsuccessful projects. The authors document a series of "implementation risk factors" and a corresponding series of implementation strategies. This inductive study was based on structured interviews with designers and users of fifty-six systems. They identified eight risk factors and sixteen strategies. The implementation factors are courses of action to be undertaken to eliminate the risk factors (inhibiting strategy) or to reduce their impact (compensating strategy).

In a later study, Ginzberg (1981) attempts to identify generic issues which arise recurrently throughout the implementation process and to assess the importance of these factors for determining implementation success or failure. In effect, Ginzberg combines research involving critical success factors with process models.

Schultz, Slevin and Pinto (1987) synthesise the approaches of critical success factors with process models of implementation. Drawing on project implementation and strategic planning literature, they identify ten factors associated with implementation success. They further segregate these critical success factors into a two-stage model involving a strategy phase and a tactical phase. Strategic planning factors include project mission, top management support, project schedule or plans. The tactical issues, which operationalise the strategic objectives are client consultation, personnel, technical tasks, client acceptance, communication feedback and trouble shooting.

Zmud and Cox (1979) also view implementation as a series: initiation, strategic design, technical design, development, conversion and evaluation. They describe the implementation process from two perspectives:

The traditional approach identifies the systems analyst as the major force in implementation. Directing each of the implementation stages, the systems analyst engages in learning, analysis and synthesis activities while the intended user of the MIS is only passively involved through responding to specific inquiries by the systems analyst.

The change approach emphasises the joining together of the systems analyst and the user as a problem solving team to discover an appropriate solution through mutual teaching and criticism.



According to Zmud and Cox, while both approaches are viable, the change process is preferred when substantial organisational change is anticipated.

They also consider the roles adopted by and the interrelations among implementation participants and the role of education and training in implementation. They identify six classifications of participants: top management, functional management, operating management, operating personnel, system analyst and system personnel. They propose that the level of involvement of the participants varies with the stage of the implementation and the class of participant. Additionally, the education process also varies by class of participant and the stage of implementation. Though the authors highlight the importance of involvement and training, it is not based on empirical research.

Srinivasan and Davis (1987) suggest that process models, which served a purpose in earlier implementations, are rapidly obsolete and are applicable to only a small portion of system implementations.

...the process approach is inadequate for the systematic study of the implementation problem. This inadequacy is particularly significant in contemporary information system environments with a wide variety of systems and usage modes.

Srinivasan and Davis (1987) point to Ginzberg's (1981) paper as evidence that "the sequential handling of issues that is implicit in the process model literature may not be valid for present day systems." They indicate that the underlying assumptions of the process model approach to implementation may no longer be valid, particularly for a large subset of systems. Their assumptions are:

Implementors or interventionists are change agents.

The user group or the members of the client system are somewhat recalcitrant and resistant to change.

User groups are relatively homogeneous.

Each of the phases in the model have to be successfully traversed in some order to produce good implementation results.

Srinivasan and Davis propose an alternative approach in which the environment meshes with the needs of a diverse set of users. They suggest the use of prototyping to ensure user participation and stress the importance of an adequate structure to support users with development tools and

training. They also advocate the introduction of intermediaries to facilitate interface between the system and users. The proposition that process models of implementation are becoming obsolete, while interesting, lacks supporting empirical evidence.

Implementation of advanced manufacturing technology has been described as a journey rather than a destination. Process models, reliant upon distinct, sequential stages, may not be applicable. Arguments advanced by Srinivasan and Davis, while untested, point out the problem with some of these earlier models, particularly when applied to complex, integrated systems such as CIM. The model proposed by Shultz, Slevin and Pinto (1987) appears to be much more applicable for implementation of AMT, where critical success factors are associated with both strategic and tactical phases. In addition, the "change model" (Zmud and Cox, 1979), is more closely aligned with the process used in implementing complex automated systems.

#### 2.3.4 Empirical Studies

As noted earlier, the literature is comprised of studies from a variety of sources (empirical research studies, single and multiple case studies, anecdotes, rules of thumb and so forth). This section will discuss the limited number of empirical studies specifically addressing implementation of AMT, as well as summarise the information drawn from other sources.

Fossum (1986) conducted a study of twelve manufacturers at various stages of automation in order to develop a normative model of CIM implementation. The research focused on integration issues to propose reasons for slow progress toward CIM by U.S. manufacturers to suggest factors that address these issues. In addition, the study developed guidelines for firms pursuing integration. Data was collected using a very detailed and extensive mailed questionnaire. He identifies a list of factors important in the CIM implementation process, including a formal plan, a steering committee, a full-time project manager, formal implementation teams of participants, user participation, substantial education and training, a strong technical staff, and good vendor-user relationships. This study offers 41 guidelines to assist management with the implementation of CIM. Similar to Dean's (1987) in-depth examination of the justification process, the number of firms studied is

too small to be representative or to allow for any meaningful statistical analyses.

An extensive exploratory study was undertaken by Rosenthal (1984) to identify progress being made and the barriers being faced by manufacturers who are implementing automation technologies. Three surveys were conducted: (1) a "user" survey targeted at organisations that were leaders in adopting factory automation; (2) a "vendor" survey aimed at the major suppliers of the automation technologies; and (3) an "expert" survey designed to test preliminary findings from the first two surveys. This study is notable in that it included a broad range of technologies rather than one particular type, such as robotics or CAD. Since adoption and implementation of automation projects vary from numerical control machines to robotics and fully integrated automated systems, this study grouped results in four categories reflecting the level and stages of automation.

The results of the user survey identify several implementation issues including: identification of a full-time project manager within the business unit; reliance on suppliers for installing and testing hardware or software, operating training, on-site trouble shooting and general consulting; development of training and retraining programmes for operators and supervisors; determination that implementation time depends on previous experience of the user and supplier, relation between the existing base of manufacturing technology and the extent and skill of the implementation team; and modification of production activities, including work measurement and standards, quality control and inspection, production control, routing and maintenance. However, incentive or reward systems were rarely modified.

This exploratory research by Rosenthal provided information about how factory automation is currently proceeding in the U.S. and a "sense" of the factors that will affect future development. Rosenthal points out that a fundamental problem with this type of research is:

Our notion of progress must be rather subjective, since no firm baseline exists on the status of factory automation across a large random sample of U.S. manufacturers.

The author also emphasises the need for empirical research to shift from surveys to in-depth case studies.

Responding to the need to perform in-depth case studies, Meredith (1987e) utilised a multiple case approach to report on three flexible manufacturing systems at different stages in their life cycles. The objective of this case study was to provide management with a number of "lessons learned" from firms that have had first-hand experience with automated technologies. Although this research identifies factors important for implementing flexible manufacturing systems, it makes no effort to link these critical factors with outcome measures of success.

Meredith (1987b) conducted another series of in-depth case studies over a cross-section of five manufacturers implementing factory automation in order to identify common issues and solutions. He compares a series of "postulates" typically endorsed by practitioners and the common press with the conclusions reached in the five case studies. The postulates are grouped into three categories: technical, system and managerial. These postulates are either refuted, verified, qualified or elaborated as shown in Table 2.8. Meredith's categorisation of expectations is basically the same as his earlier groupings of "critical success factors."

Ettlie (1986) attempts to determine the cause of the relative degree of implementation success of advanced manufacturing systems in the U.S.. This study focused on key elements (critical success factors) of a successful implementation strategy. The research design involved in-depth, focused interviews with fifty-five individuals in forty-one organisations. Similar to Meredith's study, the participants were either suppliers (twenty-four) or users (seventeen) of AMT. The major questions posed were:

1. What factors of the implementation strategies selected by firms distinguish the successful and unsuccessful attempts?
2. What is the most valid measure of implementation success?
3. What major and minor problems occur during implementation?
4. How are major problems overcome in successful implementations?

Table 2.9 identifies the factors, listed in order of the frequency of participant responses, determined to be critical to successful implementation strategies. These results are fairly consistent with the literature, however, the importance of the supplier-customer relationship is notable. The emphasis on this factor may be somewhat biased, given the composition of the sample.

TABLE 2.8  
GENERALLY ACCEPTED POSTULATES FOR MANAGING FACTORY  
AUTOMATION

POSTULATES	STATUS
<b>TECHNICAL</b>	
The flexible technologies have highly extended lifetime.	Refuted
Interchangeable elements in the technology provide additional flexibility.	Qualified
Evaluating and improving the existing production process should be done first.	Verified
Software is the major technical problem during implementation.	Qualified
<b>SYSTEM</b>	
Firm wide integration is an overwhelming difficulty in implementation.	Verified
The extensive infrastructure required by these technologies is commonly overlooked.	Verified
The implementation time is considerably longer than expected.	Verified
Accounting systems and other such measures must change with these technologies.	Verified
The technical benefits are the most important benefits from using these technologies.	Qualified
Flexibility is the critical advantage of these technologies.	Qualified
Strategic direction is imperative.	Verified
<b>MANAGERIAL</b>	
Flexible technologies can act as a partial substitute for management.	Refuted
Training is critically important.	Verified
People will resist automation.	Qualified
Managerial commitment is mandatory to effectively implement these technologies.	Verified

Source: Meredith, 1987b.

In response to the second question, Ettlie finds no consensus about valid measures of implementation success. Some of the measures suggested include: uptime (systems reliability), cycle time, achieving of target benefits, utilisation, reduction in work-in-process inventory, and direct labour savings. The most frequent responses to the third question about major problems encountered are: software and hardware programming, system integration, design flaws, reliability or function problems with the new systems, poor understanding of the goal, and training. This study by Ettlie, though

exploratory in nature, adds to our understanding of the implementation of AMT and the implementation process in general. Further research to verify results in other settings is needed.

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TABLE 2.9  
FACTORS CRITICAL TO A SUCCESSFUL  
IMPLEMENTATION STRATEGY

---

- |     |   |
|-----|---|
| 1.  | Supplier-customer relationship                  |
| 2.  | Product-process dependency                      |
| 3.  | Strategy  |
| 4.  | Training  |
| 5.  | Computer Integrated Manufacturing (integration) |
| 6.  | Incremental implementation strategy             |
| 7.  | Human resource policy                           |
| 8.  | General management support                      |
| 9.  | Champion  |
| 10. | Participation                                   |
| 11. | Justification                                   |
| 12. | Organisational culture                          |
| 13. | Size, structure                                 |
- 

Source: Ettlie, 1986.

In general there has been a significant amount of material written about how to implement computer systems and factory automation. Many of these articles treat implementation as typical of any new technology and offer generic approaches to ensure effective implementation (Leonard-Barton and Kraus, 1985; Gessner, 1984; Meredith, 1987c and 1987d; Groover, Hughes and Odrey, 1984; and Voss, 1988 and 1990). Also, a number of books have been published, which are collections of articles, to assist management in implementing factory automation (Cousins, 1988); Davis, 1986; and Savage, 1985). In addition, there are studies focusing on the human factors related to implementation of factory automation (Argote and Goodman, 1986; Huber and Hyer, 1985).

As noted earlier, implementation of AMT requires major changes in virtually all areas of an organisation. Implementation strategies must address the very considerable technological challenges required in such systems. Management's attention has been focused on understanding the technical complexity as firms grapple with highly sophisticated and complex technologies. However, technical sophistication is not the only critical aspect of such an undertaking. One theme that runs throughout the literature is that the managerial and organisational issues of factory automation has largely

been ignored. In Rosenthal's (1984) survey of "experts", ninety-five per cent responded that the toughest problems were managerial.

The role played by workers in implementing AMT has consistently been underestimated. Many are quick to point out that management has been preoccupied with the "tool" and has failed to anticipate how the worker will use the tool (Clancy 1986).

Davis (1986) argues that at least four types of strategy are important in the implementation of AMT; technology strategy, manufacturing strategy, marketing strategy, and human resource strategy. The human resource strategy is important because workers and management may act as major barriers to the success of using new technology. Factors considered to be critical to the implementation in the area of human resource include: staffing (matching worker skills and abilities with new technology); education and training at all levels; retraining for those individuals displaced by the new technology; communicating with workers and middle management about the reasons for introducing the new technology and its potential impacts; preparing the organisation for the expected changes (e.g. changes in the information flow and control, power and authority, supervision and performance appraisals and so forth); developing incentives and reward systems; and effectively managing the implementation project, such as planning, feedback and control of the process. Davis (1986) summarises the importance of human resource practices to the process of implementation of AMT as follows:

Danger arises from failure to adopt advanced manufacturing technologies as well as from failure to appreciate their systemic nature. Failure to adopt them is certain to ensure continued loss of market share because of higher costs and poor quality. Failure to consider the social system providing the context for their implementation and use is sure to limit their potential.

In a later study, Ettlie (1990) tries to ascertain whether the functional experience of general managers has any link to the genesis and success of manufacturing innovation. Fifty-one U.S. plants in the process of modernising facilities by implementing new integrated, flexible automation in manufacture and assembly were studied during the period 1984-1987. The results show that firms led by CEOs with manufacturing experience are significantly more likely to implement an aggressive manufacturing technology policy.

In summary, a substantial body of literature addresses the difficulty of implementing planned changes in organisations. Studies focusing on critical success factors comprise the majority of the implementation literature. In spite of the lack of consensus regarding a single set of factors which might significantly improve the likelihood of successful implementation, a number of factors consistently emerge in the literature. Future research could extend Ettlie's (1990) work to identify a set of variables associated with successful implementation of factory automation, and to determine if these factors are the same as they are for other implementation projects. A study exploring the link between the degree of integration (i.e. Meredith's taxonomy of stand alone, linked and integrated) and the critical organisational variables is another possible direction for future research. In addition, research is needed to understand how organisations are handling the human resource aspects of implementing AMT and the impact on the firm.

In this study implementation is viewed from the overall organisational structure and the process involved at the plant level. Both the expected and unanticipated impacts on the organisation are explored. At the plant level the process of using project management teams, outside consultants, AMT vendors and suppliers is investigated to achieve a successful AMT implementation.

## 2.4 EVALUATION

Organisations adopt and implement AMT because there are benefits to be gained. Previous sections in this chapter reviewed some of the proposed tangible and intangible benefits associated with automated manufacturing systems. As noted earlier, greater emphasis is placed on the economic justification of these systems in an attempt to predict the expected benefits in relation to the costs and potential risks involved. Excessively high costs, inability to identify quantifiable benefits and enormous risk are all associated with these large technologically advanced projects, which typically extend over a number of years. Given these factors, one would expect follow-up evaluations to be of primary concern to top management. However, there is evidence that careful and accurate post-implementation audits are rarely performed in industry (Meredith et al., 1986; Fossum, 1986; Owen, 1991). Painisset (1988) raises a number of questions:



Why do few measure the benefit actually derived? Don't we know how to measure benefits? Perhaps we're worried that events will prove we overstated our claims. Possibly the full benefits haven't been achieved and we want to avoid criticism. More likely, though: Executives don't require proof of achievement; and because we don't measure the business, we don't know when we've finished implementing, so we never get around to working out what benefits we've derived.

The next section explores the issues associated with post-implementation audits. Studies specifically addressing evaluation of advanced manufacturing systems are rare. Therefore, the literature regarding the evaluation of major capital projects and information systems is briefly reviewed.

#### 2.4.1 Post-Implementation Evaluation

Information about post-implementation evaluation is drawn from a number of different areas: capital budgeting, project management, system development and operations management. The following discussion synthesises information from some of these areas to highlight the issues associated with the evaluation process.

A procedure to review and control large capital investment projects seems like a reasonable and appropriate management action. The purpose of such a review or evaluation is three fold: (1) to compare the actual benefits with the forecasted benefits, (2) to compare actual operating costs with forecasted operating costs, and (3) to take timely corrective action, if necessary. As mentioned above, this process of evaluation is not as common as to be expected.

There are a number of compelling reasons to undertake a review of a major project like the implementation of AMT. First, an audit provides verification of the profitability or savings generated by the project. Second, if managers are informed that post-implementation reviews are required and that they will be held accountable for the results, they generally will act in the best interest of the project and the company. Feedback from the audits should assist management with future estimation of costs and benefits. Third, audits may provide insight into difficulties in project implementation or operation. Feedback may suggest possible corrective actions or alternative courses of action. Finally, post-implementation reviews may provide management with more complete information which should prove helpful in reviewing and

justifying similar projects in the future (Meredith, 1987c; and Clark, Hindelang and Pritchard, 1984).

While not all projects would normally undergo a post-implementation review, one would expect audits to be performed on extremely large, expensive projects which extend over a number of years, such as implementation of AMT. Table 2.10 lists data frequently included in post-implementation audits.

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TABLE 2.10  
INFORMATION INCLUDED IN  
POST-IMPLEMENTATION AUDITS

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Number of the approved appropriation request  
Location that requested the appropriation  
Description of the item(s) purchased  
Purpose of the project  
Amount authorised  
Amount actually expended  
Estimated savings and/or return on investment  
Actual savings or return  
Reasons for variation  
Estimated versus actual project completion dates with explanation of delays  
Explanation of project cost overruns  
Action taken to correct deficiencies  
Future prospects for currently failing projects  
Detail of equipment performance  
Comments on the adequacy of accounting records needed for making a post-audit.

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Source: Pflomn, as cited in Clark et al, 1984.

Examination of this list reveals that most of the data is concerned with the economic or financial measures. Panisset (1988) suggests that two sets of measures, management and operational, should be tracked in a five step process of evaluation:

1. Define measures of the business.
2. Determine the initial measures of those measures.
3. Set targets for those measures after implementation.
4. Track values of those measures during/after implementation.
5. Compare those values with targets.

Management measures are macroscopic, cross departmental boundaries, and assess the performance of the whole business and may include traditional financial ratios and activity levels, such as inventory. On the other hand, operational measures relate to specific, absolute, non-financial

values, such as cycle time, lead time, on-time deliveries, time to market and so forth.

Review of the information systems literature reveals that most evaluations of computer based information systems have traditionally focused on efficiency-oriented measures of system performance (response time, system reliability, quantity and quality of reports etc.) or measures of effectiveness as perceived by the users of the systems (user satisfaction, perceived system quality etc.) (Srinivasan, 1985). Green and Keim (1983) had this traditional view and proposed that the evaluation process should determine whether or not a system has performed to expectations based on a broad set of criteria. They suggested a number of techniques for gathering information for a post-implementation review, including monitors to collect information on processing; costing (comparison of actual expenditure to budgeted amounts); surveys to collect information about users' perception and attitudes; and the debriefing of the project team and other individuals centrally involved with the implementation.

As discussed earlier, there are a number of different reasons for evaluating advanced manufacturing systems. In addition, it appears that a combination of techniques might be applied to the review process depending upon the purpose of the evaluation. In the case of AMT, a thorough review of all aspects of the project appears warranted, given the magnitude of such an undertaking. Unfortunately, there has not been an adequate effort in identification of criteria for evaluation or for that matter, of what should be evaluated.

If, in fact, organisations are not performing post-implementation evaluations of their advanced manufacturing technologies, then the ability to confirm or deny the proposed benefits associated with AMT is difficult, if not impossible. Moreover long-term benefits are difficult to measure even after implementation. One of the most important solutions to this problem is the establishment of rigorous post-implementation reviews. In this study, post-implementation evaluation is audited by viewing the degree of satisfaction attained and the operational benefits achieved by the use of AMT.

## 2.5 LIMITATIONS IN CURRENT LITERATURE

Various studies outlining the importance of automation have been cited in the literature. These studies are scattered across multiple disciplines and are typically found within studies of information systems, production planning and control, operations research and, financial management and control. Moreover, most of the studies on manufacturing technology to date have focused on the existence or use of manufacturing technology and its relationship to performance. There are still certain questions that are not adequately answered. Are comprehensive technology strategies being developed to plan the adoption and implementation of AMT? Is there a connection between the development of an integrated manufacturing and technology strategy and the degree of integration of AMT systems? As firms consider the adoption of AMT, are they considering the strategic, long-range implications of AMT? Can operational reasons outweigh strategic and long-range plans?

Few in-depth research studies examining the process of adoption, implementation and evaluation of AMT have been cited in the literature. Since the technologies and issues that surround AMT are complex, it is not surprising that the number of theoretical and empirical studies is limited (Voss, 1990; Ettlie, 1990; Zammuto and O' Connor, 1992). The general body of literature about AMT provides little guidance to organisations considering the transition from existing technologies to automated manufacturing technologies. As established in Chapter 1, there is a need for in-depth, integrative studies which focus on the experiences of organisations engaged in the processes of adoption, implementation, and evaluation of AMT.

There are some studies which show the importance of technology strategy and the vital role it plays in the overall business strategy of the firm. However, very little has been documented on issues critical to the effective management of technology in manufacturing.

There is a shortage of empirical research explaining the relationship between the content and process of manufacturing strategy using AMT and manufacturing performance measures. There is also a shortage of empirical studies that relates issues which are critical in the effective management of technology with performance at the business unit level.

## **CHAPTER 3**

### **RESEARCH METHODOLOGY**

#### **3.1 STATEMENT OF RESEARCH PROBLEM**

Using a multiple case research methodology, the first part of this study attempts to offer general explanations of key issues in the processes of adoption, implementation, evaluation of AMT, and its management.

The second part of the study focuses on the role of AMT and the wider issues in the effective management of technology in both manufacturing and business unit level performance of the firm. Using a questionnaire survey of the same firms as in the first part, some hypotheses are formulated to measure how the use of AMT affects the performance measures in manufacturing. The study also explores the relationship between management's commitment to technology and other key management issues in the effective management of technology with performance at the business unit level.

#### **3.2 RESEARCH METHOD: QUALITATIVE MULTIPLE CASE ANALYSES**

It is assumed that the experiences of the users of AMT and those directly involved with the implementation of these technologies can offer valuable insights. Therefore, a decision was made to make a field study to examine the key issues in their natural settings by investigating some European manufacturing firms. A multiple-case study approach was selected as the most appropriate for capturing different perspectives to explain differing behaviour of firms. For purposes of this study, the definition of a case study follows Yin (1989) and Benbasat, Goldstein and Mead (1987):

A case study examines a phenomenon in its natural setting, employing multiple methods of data collection to gather information from one or a few entities (people, groups, or organisations). The boundaries of the phenomenon are not clearly evident at the outset of the research and no experimental control or manipulation is used.

Yin (1989) notes that the case study approach has a distinct advantage over other research methods when "how and "why" research questions are being

asked, as is the case in this research. A multiple-case study approach is particularly well-suited to both explanatory and exploratory research. Other researchers have stressed the need for in-depth case studies in researching AMT (Meredith, Hyer, Gerwin and Rosenthal, 1986; and Meredith, 1987b; 1987e), and offer advice for the potential researcher in this field:

...empirical research will need to shift from surveys to carefully designed in-depth case studies. A focus on leading-edge users is appropriate. For such inquiries to be worthwhile, investigators will have to be adept at using the case study as a serious research strategy. (Rosenthal, 1984)

While multiple-case study designs offer the advantage of generally yielding more information than single-case study designs, they also demand more resources and time. The multiple-case study design allows a "replication" logic (Yin, 1989), that is, the logic of treating a series of cases as a series of experiments - each case study serving to confirm or refute the conclusions drawn from previous ones.

A multiple case-study design uses multiple data collection methods (Yin, 1989; Taylor and Bogdan, 1984). Information for this study was drawn from a number of different sources including in-depth interviews, background questionnaires and secondary data at the firm and industry level.

The scope of this research was limited to an examination of the managerial issues related to the processes of adoption, implementation, and evaluation of AMT and its management. It was not the intent of the study to examine the technical or engineering issues (eg. software programming for integration of automated systems or scheduling algorithms for flexible manufacturing systems). The study relied on a cross-sectional, static assessment of the selected firms at various stages of utilising AMT and was not a time-series or dynamic investigation.

### 3.2.1 Research Questions

The multiple case research questions are grouped into broad categories of the processes of adoption, implementation, and evaluation of AMT and its management. This grouping was made in order to extract as much information as possible from participating manufacturing organisations currently considering or utilising AMT.

The decision to adopt AMT may range from simple consideration to complex assessments of its impact on the firm depending on the scope of the project. The primary questions of interest are:

1. Why do firms decide to adopt AMT?
2. How is AMT justified?
3. Are there barriers to adoption and justification?

Implementing automated systems is a complex process which is not well understood. This process typically spans months or even years, depending on the scope of the project. Firms adopting AMT have few guidelines to assist them in the transition from existing technology to new technology. The major questions regarding the implementation process are:

4. How is the implementation process managed?
5. What is the impact on the organisation?
6. Are there barriers to implementation?
7. What factors are critical to successful implementation?

Limited information is available documenting the results of AMT implementation. Formal, comprehensive post-implementation evaluations of AMT are rarely conducted and many of the claimed improvements are based on the evaluative perceptions of users (Rosenthal, 1984). Key questions on the evaluation process of AMT are:

8. Are firms satisfied with AMT?
9. Have formal evaluations been performed?
10. Are there barriers to evaluation?

Finally with automation, firms need to manage beyond the product and process innovation stages, and the key question here is:

11. How can firms manage the development and use of advanced technology effectively?

The remaining sections describe the details of the methodology used in obtaining answers to the above research questions.

### 3.2.2 Identification of Potential Sites

The units of analysis in this study are manufacturing sites of large European organisations considering and/or utilising AMT. In order to obtain wide-ranging perspectives of AMT, diverse groups of manufacturing organisations were pursued. For example, diversity was sought in technologies used,

types of industries, sizes of operation, products, and length of experience with automated technology. The firms chosen for this study were selected from the following industries: computers and telecommunications, automobile and machinery, aerospace, and chemicals and pharmaceuticals.

A number of steps were taken to identify the manufacturing sites to be studied. A review of the literature being the first step. Empirical studies published in journals, books and trade magazines were searched to identify those organisations in the process of implementing AMT. In addition, contacts were made with local chambers of commerce and manufacturing associations. Finally, academics and the European Commission on Industry were approached. Using the information drawn from these sources, a list of approximately 75 organisations was compiled.

### 3.2.3 Participant Qualification

From the list of potential sites, it was necessary to identify a subset of organisations to participate in the study. The following criteria were developed to qualify the organisations and to determine:

That the manufacturing organisations were involved in the adoption, implementation and/or evaluation of AMT.

That the manufacturing firms were easily accessible for site visits and interviews, and that the selected firms were reasonably distributed among the four industries.

That the individuals to be interviewed were centrally involved with some key aspect of adoption, implementation or evaluation of AMT, and that these individuals were top or middle level managers or senior level technical staff who were involved in AMT projects.

That, if possible, more than one individual within a firm would be interviewed in order to provide a broader understanding of the important issues and challenges facing the firm.

### 3.2.4 Sample Size Development

The next step of site selection involved placing telephone calls to those organisations listed that met the first two criteria. A lengthy process was followed in order to discover the names of the individuals who were centrally involved with AMT. Typically, five to seven brief telephone conversations were held with various members of the firm, before identifying those to be involved.



As a rule, most individuals agreed to be interviewed on the basis of the telephone conversation and were also willing to organise a site/plant tour. However, the additional conditions imposed in most cases related to the confidentiality of the data and naming of participants and firms.

As a result of the steps taken above, 35 firms agreed to participate in the study. Efforts were made to interview a number of people within a firm wherever possible, in order to gain a broader understanding of the issues being faced. The number of people interviewed in each firm ranged from one to three. However, for statistical analysis, the responses were treated as team responses for each of the 35 firms. A thorough discussion on the interviews involved in the research project is presented in the next chapter.

Due to the exploratory nature of this study, the number of participants selected for interviews in the study was not calculated using standard size formulas. It was not the objective of this study to provide precision in testing statistical hypotheses through the analysis of the data gathered, but rather to derive an understanding of the processes of adoption, implementation, and evaluation of AMT and its management. Therefore, the approach used followed the Morton-Williams (1985) argument:

...there comes a point with unstructured information beyond which further interviews or discussions add very little in the way of insight or understanding and the researcher is advised... to avoid the danger of being swamped by too much data that cannot usefully be synthesised.

In addition, Taylor and Bogdan (1984) point out that for case studies:

...the actual number of 'cases' studied is relatively unimportant. What is important is the potential of each 'case' to aid the researcher in developing theoretical insights into the area... being studied.

### 3.2.5 In-Depth Interviews and Background Questionnaire

A semi-structured focused interview format was followed in which the questions and their sequence were determined in advance. The questions were organised into the broad categories of the processes of adoption, implementation, evaluation of AMT, and its management. Each of these categories had a series of general questions, directly related to the research questions. Each general question was followed by a series of possible probing questions. Taylor and Bogdan (1984) underscore the importance of probing:

One of the keys to successful interviewing is knowing when and how to probe. Throughout the interviews, the researcher follows up on topics that have been raised by asking specific questions, encourages the informant to describe experiences in detail, and constantly presses for clarification of the informant's words.

This approach provided in-depth responses to questions and was flexible enough to clear misunderstandings and detect ambiguities. It permitted probing into the context and reasons for answers to questions. Each interview followed the same general format. In all cases, each participant was informed about the nature and purpose of the study. In addition, participants were assured that the content of the discussions would remain confidential and anonymous.

The participants were top and middle level managers or technical staff centrally involved with the utilisation of AMT in their respective firms. Wherever possible, various individuals within an organisation were separately interviewed. For example, three separate interviews were conducted at one research site; the first with the Director of Research & Development, the second with a Project Manager and the third with a Senior Industrial Engineer.

A tour of the facility was requested to see the new technology in process of implementation and use. The combined length of the interviews and the plant tours typically lasted between two and four hours. A total of 51 face-to-face interviews were undertaken at the 35 research sites or firms. The format used for the interviews is contained in Appendix A.

Information gained from the in-depth interviews was supplemented by a background questionnaire, completed by those interviewed and returned by mail. The purpose of this questionnaire was to understand better the particular business unit and its manufacturing environment. By using a background questionnaire to provide supplementary data, the time spent during the interview was focused on the key issues. Each person interviewed was asked to complete the brief questionnaire at their convenience and return it in the stamped, addressed envelope provided. A total of 44 questionnaires were returned, giving a response rate of eighty-six per cent and the questionnaires received from the same firms were aggregated. The background questionnaire is presented in Appendix B.

### 3.2.6 Limitations

Clearly, there were a number of limitations with the method used to select the firms. First, some organisations implementing AMT may have been missed or overlooked in the process of identifying potential research sites. Second, a number of firms that would have made excellent research sites declined to participate in the study, due to confidentiality reasons and limitations of time for interviews and plant tours. Finally, because firms were engaged in different stages of the adoption and implementation process, the information across all firms was not always comparable. Several firms, that had begun the planning and justification stage, did not yet have any experience with implementation and evaluation.

While every effort was made to develop a "purposive" sample and to include a wide range of industries, technologies, firm sizes and experiences in implementing AMT, the role of opportunism in site selection cannot be denied.

A possible limitation with the interview method is the extent to which the information is biased by the participants' efforts to present themselves and their firms favourably. According to Taylor and Bogdan (1984), the following underscores this problem:

While qualitative interviews try to develop an open and honest relationship with informants, they have to be alert to exaggerations and distortions in their informant's stories... All people are prone to exaggerating their successes and denying or downplaying their failures.

Several steps were taken to avoid this responsible bias. First, questions posed during the interview encouraged people to respond in their own words and explain exactly what happened or how the particular process worked. In general, most people were genuinely concerned that an accurate impression was conveyed. Second, various individuals within the same organisation were interviewed whenever possible. This usually resulted in more complete and accurate information. Third, all participants were guaranteed anonymity, thereby reducing the motivation for them to exaggerate successes and downplay failures. Finally, the secondary evidence provided an additional cross check on the validity of the information received.

### 3.3 RESEARCH METHOD: QUANTITATIVE ANALYSIS

In this section, the research methodology used in analysing the impact of integrated manufacturing practices, using AMT within a proposed manufacturing strategy framework on competitive performance measures in manufacturing, is introduced. This section also describes the methodology used in determining the effects of some proposed factors of effective management of technology, such as the strategic role of technology, technological portfolio, investment management, and innovation management, on the performance measures at the business unit level.

#### 3.3.1 Integrated Manufacturing Practices Using AMT

The adoption of advanced technologies in manufacturing firms forms an integral component of world class manufacturing (Schonberger, 1986). Perhaps the best way to highlight world class manufacturers is to describe them as operating on an integrated manufacturing plane, which is supported by the three pillars: Computer Integrated Manufacturing (CIM), Total Quality Control (TQC) and Just In Time (JIT) (Gunn, 1987). These three pillars or practices work jointly to change the way goods are produced; in fact, their joint application has dramatically transformed the entire manufacturing function. These practices are based on the broader classification of AMT into the functional areas of design/manufacturing, manufacturing/operations and production planning and control. The practices can and do work independently, but the concept of integrated manufacturing means that they work interactively to bring together previously independent elements of production (Mortimer, 1985; and Schonberger, 1986). As Gunn (1987), describes it, integrated manufacturing:

"consists of the entire range of activities from product and process design through ... support in the field. This is one continuous spectrum. No activity can be performed along this spectrum without affecting some other part of it either upstream or downstream".

Integration of various stages in the manufacturing operation is also facilitated by independent application of each practice of integrated manufacturing. For example, JIT eliminates inventory buffers between production stages and facilitates laying out of plants by product families to eliminate physical distribution between successive stages.

A questionnaire was developed to ascertain the extent of use of these manufacturing practices by firms selected for this study. The questionnaire, presented in Appendix C, includes a total of twenty-seven items(questions) organised into three measurement scales of CIM, TQC, and JIT. Each item in each scale was measured by a five-point Likert scale. The total measure of each scale is constructed from the items within the scale. Several related questions were asked to arrive at a reliable construct for each scale.

### 3.3.2 Framework for Manufacturing Strategy Process Using of AMT

In this research a manufacturing strategy process using AMT is defined in terms of three elements: adoption, implementation and evaluation. In terms of manufacturing strategy, adoption defines how manufacturing decisions using advanced technology are made. The implementation process defines how these decisions are put into action. Evaluation refers to the satisfaction achieved and appraisal of results. These categories of the framework and their relationships are shown in Figure 3.1.

An overall manufacturing strategy refers to the specific alternatives selected during the adoption stage. The current study, for analytical purposes, defines the content decisions in terms of integrated manufacturing: CIM, TQC, and JIT. While this study is strongly influenced by a world class manufacturing paradigm, other paradigms could be adapted to this framework via changes in the strategy content categories.

The results of adoption and implementation would lead to an effective manufacturing strategy and competitive advantage in manufacturing. Competitive advantage in manufacturing is operationalised by management's perception of the firm's performance vis-a-vis its competitors, in terms of: cost, quality, delivery and flexibility.

Two scales are proposed for the measurement of the adoption of AMT: formal strategic plan and long-range plan. Formal strategic planning measures whether the plant has a formal planning process that results in a document of written mission, long-term goals and strategies. Usually this

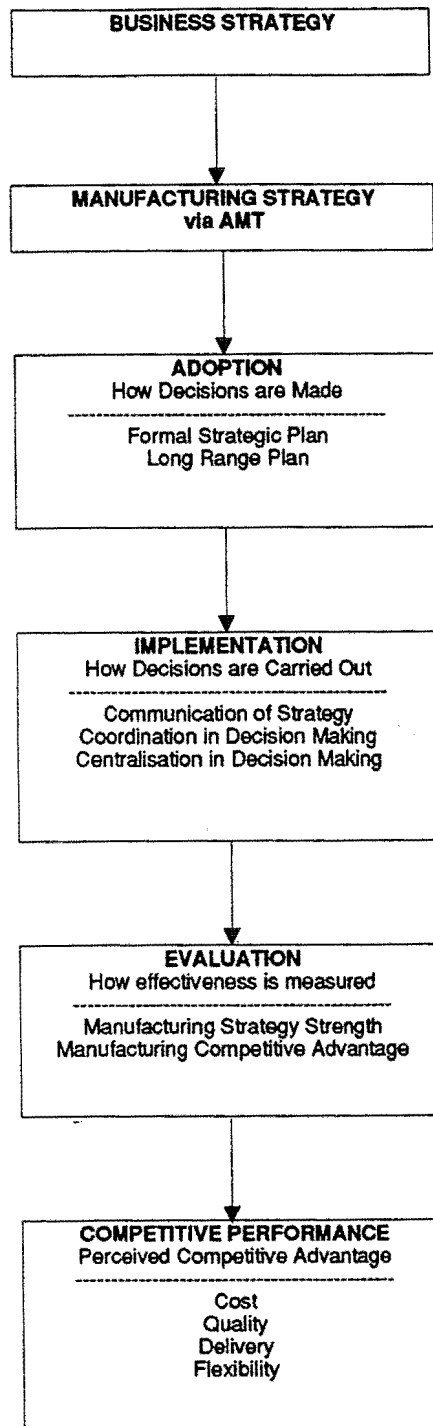


FIGURE 3.1 FRAMEWORK FOR MANUFACTURING STRATEGY PROCESS USING AMT

document describes the purpose of the organisation and its commitment to its shareholders, employees, customers, and the community as a whole. For example the long-range goals could be those of developing the supplier base to become more competitive and effecting internal improvements in manufacturing methods and process. Total quality management practices

may provide short-term improvement in performance as well as long-range perspectives for growth.

The long-range plan addresses the goal structure of management. Plant managers can have a long-run orientation focused on strategy and long-run financial concerns, or short-run focus where immediate profits and quarterly cost targets are the main concerns. A plant could have a formal strategic planning process and still be overly influenced in its formulation by short-range goals. The long-range plans could be focused on investments in new capital equipment, diversification or consolidation of product range, expansion of facility etc. This scale is included because a short-range orientation by management can undermine the effectiveness of manufacturing's strategic initiatives (Hayes and Abernathy, 1980; and Hayes, Wheelwright and Clark, 1988). It has also been seen that a long-range orientation has contributed to the success of excellent Japanese and German firms (Schonberger, 1986; and Hayes and Wheelwright, 1984).

In order for manufacturing strategy to make a difference in performance, it must play a key role in guiding decisions. This implies that it should be clearly communicated throughout the organisation; that decisions are co-ordinated between functions; and that employees are encouraged to suggest and make decisions. In other words, strategy formulation contributed very little unless the chosen strategy is effectively implemented (Miller, 1988). In this study, implementation is categorised into three scales: communication of strategy, coordination in decision making, and centralisation in decision making.

The communication of strategy measures how well the strategy is communicated to all personnel in manufacturing. Top management should openly communicate in an atmosphere of integrity and mutual trust. Employees should understand what goals they are attempting to achieve and which strategies are being implemented. They should also participate in decision making and strategy formulation. Communication of strategy is important, because without an understanding of the manufacturing strategy at all levels of the plant, the strategy cannot be used as an effective guide to decision making over time. This communication can be done through team briefing or employee involvement groups which include employees at all levels and suppliers who will create a climate of cooperative participation to ensure that the goals and objectives of the firm are met.

Hays and Wheewright (1984) emphasise the importance of integration of functions and the coordination of decisions across departmental boundaries to achieve manufacturing strategy. Coordination in decision making measures the degree to which respondents believe individuals and departments cooperate in decision making. As firms try to adopt practices like "cycle time reduction", "quality at source" and "concurrent engineering", more communication and information flows between departments are necessary. More cross-functional teams consisting of experts drawn from R&D, production, finance, marketing and sales are deployed to manage new projects to bring products ahead of competitors to the market at a competitive price.

Finally, implementation is measured by the degree of centralisation in decision making authority in manufacturing. It is thought that a more decentralised organisation will do a better job of implementation than one which is overly centralised, because decentralisation permits lower level employees to take action and to adjust to changing conditions during implementation (Govindarajan, 1988). Most firms are trying to reduce their organisational hierarchies and to push more power and decision making to the lower level staff. This instils more ownership of, and responsibility for the jobs that they are doing. Added to this, implementation of projects is accelerated as the delays in approving decisions are reduced.

The effectiveness of the evaluation is measured by two scales. A manufacturing strategy strength scale is constructed to summarise the overall existence of manufacturing strategy. This measures whether the plant is well focused, and whether manufacturing provides competitive strength in business. It also measures whether the plant has a regular system of monitoring performance against formal criteria.

Wheelwright and Hayes (1985) have suggested a way to define whether or not an organisation has an effective manufacturing strategy by determining which of four stages of manufacturing strategy best fits. These stages are fire-fighting, parity, alignment and superior competence and integration with business strategy. Fire-fighting is a stage where no strategy exists and manufacturing suffers from management's benign neglect. Parity is a stage where the firm keeps "manufacturing" alive and keeps up with the practices as to what other firms are doing. At the alignment stage the firm attempts to consolidate its manufacturing practices with the business strategy. At stage



four, the firm establishes a superior manufacturing competence and integrates manufacturing to the corporate strategy and business functions. This gives a decisive competitive edge to the firm. In this study only stage four: manufacturing competitive advantage, is used as measure to evaluate the use of AMT in manufacturing, for it is thought that most organisations have already moved through the other three stages or they would not have survived in today's economic climate.

Appendix D contains the questionnaire used in gathering information on the above framework from the participating study sites. The questionnaire includes a total of 30 items organised into the seven measurement scales for the manufacturing strategy framework using AMT. The constructs for the seven measurement scales were developed in a similar manner as were the constructs for the scales in integrated manufacturing practices in 3.3.1 above.

### 3.3.3 Competitive Performance Measures in Manufacturing

Manufacturing objectives are normally expressed in terms of four major performance measures: cost, quality, delivery and flexibility. When comparing firms with different products and product mixes, a common measure of manufacturing costs may be difficult to use. In this study, cost objectives are measured by using costs of labour and materials, inventory turnover, and product unit cost.

Quality measures include per cent defective or rejected, the frequency of failure in the field, and cost of quality. An external measurement of quality is how the product meets customer requirements. In this study, a manufacturing driven definition of quality is used by measuring it in terms of defects or percentage of products that pass final inspection without reworking. This was done because the research does not include information on customer opinions.

To measure delivery performance, percentage of on time shipments, average delays, and expediting response may be used. Overall, the best standard measurement for delivery is the percentage of orders delivered on time.

While there are many ways to define flexibility, it usually refers to the ability change manufacturing in response to changing market needs. Flexibility may be measured with respect to product mix, volume, and cycle time for new products. In this study cycle time means the time from placement of order for raw materials through production and distribution to delivery to the final customer.

A questionnaire was developed to measure the above competitive performance measures in manufacturing of the firms selected in this study. The questionnaire consists of 12 items organised into the four measurement scales of cost, quality, delivery, and flexibility (Appendix E). The constructs for the four measurement scales were developed in a similar manner as in the case of the constructs for the scales for integrated manufacturing practices described in Section 3.3.1.

#### 3.3.4 Interactive Effects of Integrated Manufacturing

A concerted effort was made in this study to define and measure integrated manufacturing more comprehensively than in previous studies. Past researchers have examined specific techniques in isolation. For example, they measured the extent to which firms have implemented CIM and other computer/automated technologies in manufacturing, without regard to their prevalence across industries. They have measured the extent to which firms use TQC techniques to promote continuous improvement, put quality at source, and fulfil customer needs. They have measured the extent to which firms use JIT in their attempts to cut costs through reduced inventories and lead times, and by controlling such features as the number of suppliers, size of deliveries, and the total number of parts.

Integrated manufacturing unites the goals of manufacturing in a synergistic relationship (Gunn, 1987). With the advent of integrated manufacturing, the goals of cost, quality, delivery, and flexibility can now support one another. For example, JIT's focus on lead time reduction also impacts on the improvement of quality and cost.

To examine the interactive affects of integrated manufacturing and the framework of manufacturing strategy process using AMT on the above competitive performance goals, the set of three questionnaires described above and presented in appendices C, D, and E were distributed to the plant

managers participating in the study. The plant managers also provided the names of functional managers, who were then asked about the facet of manufacturing pertinent to their areas of expertise: CIM for operations, TQC for quality, and JIT for production control. Responses from the functional managers were used to corroborate the information provided by plant managers. In addition, each functional manager was asked questions about his/her perception of manufacturing strategy using AMT and its relationship with competitive performance measures. Some plant managers or functional managers were also asked to distribute the questionnaires to non-managerial employees and other support staff involved with AMT. All the three questionnaires were pilot tested at ten firms before being distributed to all the firms. The respondents at each site were asked to evaluate the questions as to their clarity and relevance.

A total of 128 usable replies was received from the 35 firms. This gives an average of 3.7 replies per firm selected. The number of replies was proportional to the number of firms in the four industries. The number of replies was different for the scales for integrated manufacturing, manufacturing strategy using AMT, and competitive performance measures, because of the knowledge-specific information requested. The distribution of responses is shown in Appendix H.

### 3.3.5 Hypotheses Development for Integrated Manufacturing

One of the objectives of this research is to determine how the practices or facets of integrated manufacturing, CIM, TQC, and JIT, individually and jointly affect the competitive performance measures in manufacturing. CIM reduces labour cost as automation reduces manual labour. By using automation, lower unit cost with reduced volume can be achieved. With TQC there is more employee involvement, employees working jointly on specific projects to reduce cost. Application of JIT reduces the number of suppliers and also buffer stocks, thus providing cost savings. These arguments lead to the following hypothesis on the effects of CIM, TQC, and JIT on cost:

Hypothesis 1a: Facets of integrated manufacturing practices using AMT (CIM, TQC, JIT) are positively related to cost.

With the use of CIM significant improvements on process quality can be effected, as these complex machines have the capabilities to achieve and

maintain product quality continuously to the strictest tolerance. TQC helps to develop tools, such as statistical process control, which provides a measurement system for continuous improvement in quality. JIT also maintains quality during work-in-progress between workstations in the plant as unacceptable parts are not permitted to move to the next workstation for processing. These arguments lead to the following hypothesis:

Hypothesis 1b: Facets of integrated manufacturing practices using AMT (CIM, TQC, JIT) are positively related to quality.

CIM provides competitively short production cycles thus ensuring smooth delivery for all finished products from the plant. TQC promotes better co-operation between the supplier and the plant to ensure correct delivery practices in raw materials and semi-finished parts. JIT maintains a synchronised movement of goods from the suppliers, within the plant and to the final customers, thus avoiding any delivery delays. Thus:

Hypothesis 1c: Facets of integrated manufacturing practices using AMT (CIM, TQC, JIT) are positively related to delivery.

CIM helps to introduce new products quickly and also in increasing product mix, thus providing flexibility. TQC facilitates teamwork and promotes cross-functional working, thus increasing flexibility in operations. For small batch sizes and quick change over in product mixes, JIT with the use of the Kanban system provides accuracy and flexibility in production planning. These arguments suggest the following hypothesis:

Hypothesis 1d: Facets of integrated manufacturing practices using AMT (CIM, TQC, JIT) are positively related to flexibility.

The simultaneous use of all three facets of integrated manufacturing places the highest demands on the plant, making the importance of the competitive performance measures greater than it is with a single facet. On the basis of this and the arguments outlined under Hypotheses 1a - 1d, the interactive effects of CIM, TQC, and JIT on the competitive performance measures in manufacturing are hypothesised as follows:

Hypothesis 2a: The interactive effects of integrated manufacturing practices using AMT (CIM, TQC, JIT) are positively related to cost.

Hypothesis 2b: The interactive effects of integrated manufacturing practices using AMT (CIM, TQC, JIT) are positively related to quality.

Hypothesis 2c: The interactive effects of integrated manufacturing practices using AMT (CIM, TQC, JIT) are positively related to delivery.

Hypothesis 2d: The interactive effects of integrated manufacturing practices using AMT (CIM, TQC, JIT) are positively related to flexibility.

### 3.3.6 Hypothesis Development for Manufacturing Strategy Process Using AMT

This study examines the manufacturing strategy process using AMT at the plant level. While the content of manufacturing strategy may differ depending on the firm's positioning and the type of industry, the process of formulating manufacturing strategy using AMT should be more similar across organisations.

A well coordinated and integrated manufacturing strategy using AMT should enable the plant gain a competitive advantage and a high level of manufacturing performance. The study provides a framework to explore the relationship between manufacturing strategy processes of adoption, implementation, and evaluation with the competitive performance measures. It is hypothesised that the seven measurement scales in the manufacturing strategy framework described under section 3.3.2 and presented in Appendix D are related to the competitive performance measures in manufacturing:

Hypothesis 3: The manufacturing strategy process (adoption, implementation, and evaluation) using AMT is positively related to the competitive performance measures in manufacturing (cost, quality, delivery, and flexibility).

## 3.4 EFFECTIVE MANAGEMENT OF TECHNOLOGY

To benefit from advanced manufacturing technology an organisation needs to manage its creation of products and processes. It is necessary to integrate technology and business strategies, exploit synergies across business units and assess opportunities and threats with new technologies. In order to effectively manage these issues, four measurement scales for the effective management of technology are proposed in this study.

The first scale recognises the strategic role of technology by determining how technology intensive is the business. Is the final product driven solely by a consideration of technology? Also taken into consideration is the strategic impact of technology on the business. Should the firm be characterised as one bringing out innovative products with new and superior features that the firm's competitors are not able to produce? Finally, are technology considerations explicitly reflected in the way the firm develops its strategies?

A second scale is used to determine the management of technological portfolio. In this, one has to consider if the firm has the "right" technology mix for its business needs. If the firm is engaged in the production of hi-tech products, it should be exploiting the latest technology available in this area. The firm also has to consider if it is failing to introduce any important technology so that its competitors do not gain the advantage of introducing technologically superior innovative products ahead of it.

The third scale considers the "hard" side of technology, which is investment management. Is there an effective balance between the short-term and long-term demands? A firm should be able to invest in proven technology in the short term to further enhance its products and processes. At the same time, it should also plan for investments in the future in line with new product creation. The allocation of investment should also be in line with the strategic importance of technology as related to products and processes. For example, if the core business of the firm is the production of semi-conductors, then the investments should relate to the latest technology available in this particular area so that the firm can produce much superior products in terms of cost and quality when compared to its competitors.

The final scale measures the "soft" side of technology or innovation management. This is much more difficult to quantify, but is still an important factor. In this scale, one should consider if the firm is organised for maximum technology effectiveness. The optimum distribution of resources in terms of the right mix of skills and talents of people are necessary. Is the firm using a co-ordinated way to exploit the technical know-how from the various businesses to break new technological grounds? Procedures should also be developed to identify and eliminate obstacles and risks to innovation. The questionnaire on the proposed measurement scales for effective management of technology is shown in Appendix F. A total of 12 items organised into the four measurement scales are used. A construct for each measurement scale is synthesised from the items within each scale by aggregating the response to these items.

To assess the effects of effective management of technology at the business unit level, three additional measurement scales are considered. These are profitability level, generating increased sales, and creating new opportunities and facilities. Profitability level measures how well the business unit meets its financial objective. Generating increased sales will

show how well the business unit is doing in achieving sales objectives and creating future orders. Creating new opportunities and facilities is a measure that determines how successful the business unit is in taking advantage of new opportunities of new products and in new markets. The measurement scales for the performance factors at the business unit level are shown in Appendix G. Six relevant items are organised into the three measurement scales. Constructs for these scales are also developed by aggregating the responses to the individual items within the scales.

To examine the effect of the key issues in management of technology on the performance factors at business unit level, the questionnaires (presented in Appendices F and G) relating to these issues were distributed to the 35 plant managers participating in the study. Though this number was small, it was decided that the same sample would further bear consistency and continuity in the study. These plant managers are individuals responsible for manufacturing and, at the same time, had an understanding of the impact of technology on the business performance measures of their firms. They also had an appreciation of the importance of integrating technology with the firm's business strategy. The questionnaires were also pilot tested at five firms for clarity and understanding before distribution to all the participating firms. All the plant managers returned the completed questionnaires.

The results obtained from the above study are presented in two chapters, qualitative results for the multiple case analyses in Chapter 4 and quantitative results in Chapter 5.

## **CHAPTER 4**

### **RESULTS OF MULTIPLE CASE ANALYSES**

#### **4.1 INTRODUCTION**

This chapter presents the results of qualitative analyses of the multiple cases of the management processes of adoption, implementation, and evaluation of AMT and its management.

Written analysis of multiple case studies may take any number of forms. One approach is to present each individual case as a narrative to describe and analyse the information acquired. A second approach describes individual cases in traditional narrative form, but also includes a section covering cross-case analysis and results. A third format for the written analysis does not include separate sections devoted to individual cases. Rather, the entire discussion consists of the cross-case analysis.

The presentation of the results of this multiple case research follows this third approach. It is not the purpose of this research to present any single case. Rather, it is the intent to synthesise the information obtained from all the case studies. Throughout this chapter, examples are drawn from the individual cases without presenting the thirty five cases in a narrative format. This approach permits discussion of the relevant issues while preserving anonymity.

From the face-to-face interviews, the responses of the participants were analysed for structural comparisons. The data was examined to identify emerging themes and patterns. The search for patterns was assisted by categorising firms in a variety of dimensions: industry, extent of automation, stage of planning and implementation process etc. Piore (1984) indicates that this is often the main product of interview research:

...what interviews can reveal is not a set of specific answers to specific questions, individual bits and pieces of information. What they reveal are patterns of responses. Each answer, whether true or false, is a piece of pattern. Individual responses cannot be interpreted in isolation. But the responses grouped together, taken as a whole, are clues to the mental processes of the economic participants.



From the themes and patterns that emerged, and supporting evidence from individual cases where appropriate, key issues in the management processes are identified.

## 4.2 RESEARCH SITES AND PARTICIPANTS

As noted in Chapter 3, the actual in-depth interviews were conducted on an individual basis. At some of the firms, more than one individual was interviewed, because these individuals would have had different experience or expertise with different aspects of the management processes involved (eg. justification of AMT or implementation of projects). Altogether 51 responses to each question were obtained from the 35 participating firms. However, the multiple responses from a firm were treated as a team response from that firm.

The firms selected were all located in Europe: Belgium, France, Germany, Italy, the Netherlands, Switzerland and the United Kingdom. Many of the firms are subsidiaries or divisions of large, widely diversified corporations, and most of them are also multinationals with operations in different parts of the world. Thirty of the thirty-five firms were included in the list of Fortune 500 corporations in 1992.

Job titles of the participants interviewed varied from Plant Managers, Director of Manufacturing, Director of R&D and Project Managers to functional Managers in Quality, Production and Operations and Senior Technical Officers. Top management is typically involved with approvals during the justification process. In addition, some top level managers were strong proponents or "champions" of automation. However, in general, top corporate management was often removed from the processes of adoption and implementation.

The results are presented in aggregate for all the firms and not separated into the four industry sectors owing to the small sample size in each sector. Although automation may vary in different industry sectors, it can also differ from firm to firm within each sector and with the age of an individual plant. Moreover, in this study, the firms were at different stages of utilisation of automation. The approach is to present a global view of management processes of automation across all the firms studied, even though types of

AMT may vary from firm to firm, and industry to industry. Some aggregate public domain information of the firms participating in this study are given in Appendix I.

#### 4.2.1 AMT Implemented

The participating firms varied in degree and sophistication of automated systems implemented, as shown in Appendix J. Some firms are completing justification of their proposed systems and have not yet begun implementation. All others are either in the process of implementation or evaluation. Clearly, the range of technologies is very broad and the extent of integration is varied across industries. For example, some firms have only implemented a minimum amount of automation, consisting primarily of stand-alone systems. In general, stand-alone technologies (eg. CAD, robotics etc.) are implemented most frequently. Other firms have linked together numerous systems, such as CAD and CNC machines or flexible manufacturing systems; however, these systems do not necessarily tie together with the firm's other systems. In a few organisations there is extensive integration of automated manufacturing systems with business and engineering databases. These firms are approaching CIM, the overall system integrating all aspects of the business.

It may be seen from Appendix J that the most extensive and highly integrated systems are found in the computer and aerospace industry. On the other hand, chemicals and pharmaceuticals firms have implemented few advanced technologies, and an examination of the four industry sectors reveals some reasons. For example, computers/telecommunications and aerospace industries may be characterised by their relatively new, post-war development and expansion. On the other hand, machinery and chemicals/pharmaceuticals are older industries and there appears to be a relationship between the degree of automation and the age of the industry (Table 4.1). Older industries appear much less automated, while younger industries appear much more extensively automated. This might be explained by more conventional conservative management in the older industries compared to more non-traditional, liberal management in the younger industries. Another explanation may relate to the degree of investment in capital equipment. Older industries may be heavily invested in conventional capital equipment, which discourages them from adopting new,

automated technologies. This may not be true, for example, in the computer and aerospace industries. Investigation of the literature on early adoption of leading-edge technologies may throw some light on this subject. However, further investigation of the relationship between age of the firm (industry) and the degree of automation may be warranted.

Table 4.1  
DEGREE OF AUTOMATION BY INDUSTRY AND AVERAGE AGE

INDUSTRY	DEGREE OF AUTOMATION		
	EXTENSIVE	HIGH	MEDIUM
Computer/Telecommunications	X		
Automobile/Machinery		X	
Aerospace	X		
Chemicals/Pharmaceuticals			X
INDUSTRY	AVERAGE AGE		
Computer/Telecommunications	20 years		
Automobile/Machinery	72 years		
Aerospace	35 years		
Chemicals/Pharmaceuticals	83 years		

There may be a relationship between the degree of automation and the size of the firm. Perhaps only very large organisations have the financial and human resources available to pursue an active strategy of AMT. However, more detailed analysis is necessary to warrant any firm conclusion.

#### 4.3 RESULTS: ADOPTION

This section reports on the management process involved in the adoption and justification of AMT. First, the reasons why firms chose to adopt AMT are discussed. Second, the role played by manufacturing and technology strategies in this process is presented. Finally, since the literature indicates that economic justification of AMT has proven to be an extremely difficult task and a major barrier to adopting AMT, attention is focused on the justification process.

#### 4.3.1 Adoption of AMT

Review of the literature reveals that the strategic ramification of implementing AMT outweigh the operational or tactical consequences. The focus should be long-range, emphasising strategic advantages, such as improved flexibility, ability to respond to customer demand, decreased time to market, and improved product quality. With conventional equipment replacement decisions, management has traditionally looked for higher volumes at lower unit costs. However, flexible automation offers the potential to produce in extremely small lot sizes while maintaining quality and responding to market. Gold (1982) proposes that if management views AMT from an operational cost reduction perspective, the technology used will tend to reflect this. As a result, the potential for strategic innovative applications may be ignored.

In order to understand why manufacturing organisations are actually adopting and implementing AMT, individuals participating in this study were asked to respond to the question: "Why was the decision made to implement

TABLE 4.2  
REASONS FOR ADOPTION OF AMT

STRATEGIC	FREQUENCY	PER CENT
Maintain/Improve Competitive Edge	31	89
Improve Quality	26	74
Leading Edge of Mfg Tech.	17	49
Increased Capacity/Expansion	12	34
Market Perception and Image	11	31
Market Responsiveness	9	26
Survival	9	26
Improve Productivity	7	20
Improve Flexibility	2	6
OPERATIONAL	FREQUENCY	PER CENT
Reduce Manufacturing Costs	20	57
Reduce Labour (direct/indirect)	15	43
Reduce Inventory	7	20
Improve Safety	5	14
Reduce Delivery Time	5	14
Reduce Cycle Time	5	14
Other*	2 or less	

\* Other includes: reduce scrap, reduce floor space, reduce set up times.

advanced manufacturing systems?" The responses are summarised in Table 4.2. The table is organised in two broad categories: strategic and operational reasons. The frequency of reasons mentioned is listed, together with the percentage of participating firms. In addition, the responses have been rank-ordered within these two categories. In some cases, the respondents cited multiple reasons for deciding to adopt AMT.

As seen in Table 4.2, while there is no consensus, the range of reasons was predictable and generally matched those proposed in the literature. The five most frequently mentioned reasons for adopting AMT were to: maintain or improve competitive advantage, improve quality, reduce manufacturing costs, stay on leading edge of manufacturing technology, and reduce labour. Three of these five can be classified as strategic reasons. While management has been criticised for ignoring the strategic implications of emerging technologies, it appears that this group of individuals perceive that there are strategic advantages to be gained with the use of AMT. The results also correspond to the information from the background questionnaire shown in Appendix I. Here improving product quality and reducing manufacturing costs are of top priority.

The frequencies listed in Table 4.2 can be somewhat misleading because all industries are combined together. In general, the firms in automobile/machinery and chemicals/pharmaceuticals industries cited operational reasons more frequently than strategic reasons. However, the firms in computer/telecommunications and aerospace industries mentioned strategic reasons for adopting AMT with more frequency. This may be why the degree of automation is extensive in this group of industries. In effect, the firms citing strategic reasons for adopting AMT are extensively/highly automated (Table 4.3). On the other hand, the firms citing operational or tactical reasons generally have medium levels of automation, as shown in Table 4.3

Further investigation across a broader sample of organisation is necessary to determine if such relationship exists between the strategic/operational reasons for adoption of AMT and the degree of automation. However, the implication is that companies with strategic, long-range outlook tend to adopt and implement more extensive and integrated AMT systems than companies with an operational, short-range outlook.

TABLE 4.3  
DEGREE OF AUTOMATION COMPARED WITH  
REASON FOR ADOPTION OF AMT

REASON FOR ADOPTION	DEGREE OF AUTOMATION	
	EXTEN./HIGH	MEDIUM
Strategic	X	
Operational		X

This may be illustrated by several examples: adoption of a robot, a stand-alone system at a relatively low cost, may be considered strictly for its ability to improve safety in a hazardous work environment and to reduce direct labour. Both of these operational considerations are extremely important in the chemicals/pharmaceuticals industry, where in some cases shortage of direct labour is causing serious problems in meeting production volumes.

The firms in the computer/telecommunications industry primarily identified strategic reasons for adoption of AMT. In general, these organisations were considering fairly complex, highly integrated systems. For example, the participants reported competitive advantage, quality, market perception, and market responsiveness with the greatest frequency. One of the reasons a production manager gave for adopting AMT was to defend the firm against the competitive threat from the Far East.

The most frequently mentioned reason for adoption of AMT was to maintain or improve competitive advantage, which was mentioned in 89 per cent of the cases. One explanation for this response was that everyone else was doing it, so they needed to do it as well. In particular, firms in the aerospace industry emphasised the importance of remaining competitive.

Everyone else, in particular.....(our main competitor), is doing it and we have to remain competitive.

In addition, the threat of foreign competition was frequently mentioned as an impetus to adopt AMT:

The threat to us is international. The Koreans, Chinese and Japanese...make the competitive aspect of our business very life threatening.

We are faced with business pressure and foreign competition, being able to deliver not the same product but an equivalent product at a significantly lower cost, like 30 to 40 per cent, at a significantly reduced schedule.

Seventy-four per cent of the firms mentioned improvements in quality as a reason for adopting AMT. Most of the firms were in the process of implementing a major programme to manage quality. AMT, such as robotics, were perceived as being instrumental in improving product consistency and repeatability. In addition, systems to automatically track defects and rejects were being implemented in order to provide understanding of the problem areas.

Staying on the leading edge of manufacturing technology was stated in 49 per cent of the firms. This has been an area where European manufacturers have been criticised for allowing deterioration of plant and equipment over the last several decades. In one instance, an aircraft parts manufacturer made a strategic decision to bring production of a particular component in-house. In doing so, the firm needed a new facility and there was a push to build a highly automated factory.

People reported that new technology offers faster, more accurate and new capabilities. For example, some new "space age" materials must be processed by highly sophisticated equipment, conventional machinery simply does not work. In some cases, firms have teams of people investigating new technology to determine if it can be beneficially utilised. A senior manufacturing engineer at an aircraft manufacturer explained: "This company is always looking at new technologies. We have 70 to 80 people doing just that." Another aerospace firm has a "New Technology Group", comprised of ten to twelve managers, including the president of the company. They meet quarterly to discuss all new technologies being introduced.

In some of these examples, top level managers were often responsible for moving the organisation in the direction of automation. While the reasons may have varied, there were a number of firms where one key individual or "champion" was the driving force in adopting emerging technologies. Another example from the automobile/machinery industry further illustrates this phenomenon:

The plant manager for the company became very vocal on the point that if you don't start introducing new technology and if you don't start looking at automation, if you don't start looking at ways to improve your design capabilities, the company is going to die. He was one man preaching automation. He got the ear of the CEO.

If the proposal to adopt AMT is initiated from top management rather than from lower levels in the organisation, the justification process may follow different routes. This is discussed in more detail in section 4.3.3.

In summary, there are many reasons why firms adopt AMT. There are a variety of strategic and operational forces pushing companies in the direction of AMT, and the impetus to investigate these emerging technologies may come from almost any level in the organisation.

As a follow up question, participants were asked to respond to the following: "Do you believe AMT is currently a competitive necessity within your industry?" The responses of the thirty-five firms are summarised in Table 4.4. This also justifies the response from the background questionnaire in Appendix I, where 89 per cent of the firms included the decision to implement automation in their strategic plan.

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TABLE 4.4  
COMPETITIVE NECESSITY FOR ADOPTING AMT

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RESPONSE	FREQUENCY	PER CENT
Yes	32	91
No	2	6
Missing	1	3

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Thirty-two firms (91 per cent) responding "yes" to this question offered some of the following explanations: (1) Foreign and domestic competitors are implementing AMT and there is increasing pressure to follow suit; (2) AMT is necessary for survival in such a highly competitive environment; (3) Implementation of AMT is important to portray a high-tech image to the external environment; and (4) conventional equipment cannot handle new, high technology materials and process.

Each of the "no" responses were qualified. These firms felt that AMT, an overall, integrated approach, was not applicable to all firms. However, each



of them acknowledged that some of the various advanced manufacturing technologies may be necessary and appropriate to maintain competitive advantage. In particular, they focused on understanding the business and the process first before diving into automation, acknowledging the fact that some automated technologies may be appropriate. In other words, the message was: Don't automate for the sake of automation.

#### 4.3.2 Strategy

In order to explore the role that manufacturing and technology strategies play in the overall strategic plan of the firm, participants were asked if their firms had a formal strategic plan. Table 4.5 lists the responses by industry.

The responses to this question are somewhat surprising. It was expected that far fewer organisations would have a formal strategic plan, given the information available in the literature. However, eighty per cent of the participating firms appear to have some form of formal strategic plan. In these firms, manufacturing did have an input into the planning process, and

TABLE 4.5  
EXISTENCE OF STRATEGIC PLANNING

INDUSTRY	RESPONSE	
	YES	NO
Computer/Telecommunications	9	2
Automobile/Machinery	6	2
Aerospace	7	1
Chemicals/Pharmaceuticals	6	2
Total	28 (80%)	7 (20%)

in some cases, developed a separate manufacturing strategic plan. The response from the background questionnaire in Appendix I show that 84 per cent of the firms have a formal strategic plan for manufacturing. The typical planning horizon was three to five years; however, in the aerospace industry, strategic plans were developed over twenty years in some cases. The computer industry, on the other hand, generally has planning horizons between one and five years, primarily due to shorter product life cycles.

In addition, a capital plan is usually prepared to support the manufacturing and business unit strategic plan. For example, if the manufacturing strategy is to implement AMT actively to remain competitive, ensure high quality, stay on the leading edge of technology, and so forth, a specific capital plan is often developed on a year by year basis specifying the projects to be undertaken. In a number of cases, the plan for several years was sometimes approved "carte blanche"; however, more often than not, the plant or division needed to have each item on the capital plan approved in the appropriate year.

In Table 4.5 the responses are classified as "no" if the participants indicated that there was only an informal plan or no strategic plan. In some organisations, there are a number of "strategic intents" or broad organisational goals, however, they are generally not published in a formal document or backed up by a detailed plan. For example, an operations manager in machinery industry described the mission of manufacturing as: "To provide quality products to meet customer expectations, on-time, at a reasonable cost." Also, several individuals noted that there was a move toward a more formal strategic plan and it was an evolving process. Another participant in an aerospace firm responded:

A strategic business plan? We're not aware of one. We have goals but they are not published. There is a lot of ad hoc stuff. Also, everything is so confidential that there is very poor communication across areas. Sometimes we do things that are diametrically opposed.

This "fuzzy" perception identifies some of the dangers associated with not developing an overall strategic plan for adoption and implementation of AMT. It is easy to understand how "islands of automation" might spring up within the company based on this approach. While this might be a reasonable approach for the organisation wishing to adopt and implement a few, small stand-alone systems, the risks may be significant if an overall, integrated set of manufacturing technologies are being considered.

While the results of this study are limited, one might conclude the following: firms with an overall strategic business plan, supported by strategic manufacturing and technology plans, implement more extensive and fully integrated automated systems than firms which do not have such a plan.

### 4.3.3 Justification

This section describes the results of the justification process, examines the obstacles to justifying emerging technologies, and discusses how the firms have tried to overcome these obstacles.

Justification typically follows a standard process. Dean (1987) identifies the required steps.

The basic structure of AMT justification decisions derives from their place within the capital budgeting framework. Requests to expend capital come from lower levels in the organisation and must be approved by managers at successively higher levels. If a manager at any level turns down a request, it does not progress to the next level. Requests for larger amounts of capital require higher levels of approval, although organisations obviously differ on the amount of discretionary spending allowed at various levels.

In general, justification of AMT follows the same process as justification for any capital investment. The firms in this study followed the process described by Dean. The first step in the process requires that lower level technical personnel or middle management prepare an appropriation request or project proposal for approval from the higher levels of management. This usually involves a description of the project, a detailed identification of the expected costs, a list of anticipated benefits, and sometimes identification of possible risks.

Standard forms (eg. Capital Appropriation Request), together with formal presentations, are typically used to attain approval up through the various levels of the organisation. Depending upon the organisation, four levels of participants are involved in the process: (1) technical personnel, (2) middle management, (3) top management, usually the president, and (4) management at the corporate level, if the company is a division or subsidiary of a parent corporation. At each successive higher level, the management is further removed from the specific details of the manufacturing processes and needs at lower levels. As a result, the focus at the top level typically shifts to become a purely economic or financial decision, and the project is so evaluated and ranked with many other proposals. As will be shown later, this arm's length involvement of top level management was often perceived by participants as a major obstacle in the justification process.

The length of the decision making process varied widely across firms. The elapsed time from idea initiation to final approval of the project ranged from one day to over five years. The justification process averaged approximately four to six months. In many instances, the length of time required depended on the complexity of the proposed systems, the experience of the organisation with the technologies, and the number of approval levels. However, these was not clear-cut from this sample and a general pattern did not obviously emerge.

The most common investment analysis methods included payback and return on investment (ROI), with fewer firms calculating net present value (NPV) and internal rate of return (IRR). The rationale given for the use of payback and ROI was ease of understanding and simplicity of calculation. For all the firms involved in this study, the acceptable payback period ranged from one year to a maximum of three years. This period varied by industry, with the computer industry usually requiring shorter payback periods than the other industries.

As expected, the cost of proposed AMT systems varied across the sample firms. Project costs ranged from approximately U.S. \$200,000 for a stand-alone robotic system to well over U.S. \$100 million for a new, automated "factory of the future". Aerospace firms, the most highly automated of the organisations studied, had extremely high project costs with numbers being in the neighbourhood of U.S. \$25, U.S. \$50, and U.S. \$100 million. In several cases, the firms were either unwilling to divulge the cost or did not have any idea of the total amount of money spent for the automated systems.

When queried about the costs to be included on the appropriation request, most individuals had prepared a very detailed analysis of costs. As discussed earlier in Chapter 2, these include hardware, software, internal and external programming and debugging, training, facility planning, site preparation, tooling, fixtures etc. Usually costs are fairly well defined, especially for stand-alone systems or if the organisation had prior experience in implementing the technologies. In many cases there were rigid rules imposed by the financial management, requiring precise identification of vendors and specific details of equipment. Managers in one aerospace firm complained that even if a newer, faster, cheaper piece of

equipment was introduced by a vendor after the firm had gained approval for the capital appropriation request, they were still required to purchase the more expensive equipment originally identified and approved in the process.

Invariably some factors were overlooked that were responsible for additional costs during the project implementation. For example, delayed equipment delivery by vendor(s), difficulty in interfacing multiple systems, debugging hardware and software problems, all led to implementation schedule delays and problems with maintaining current production volumes, and, as a result, higher costs. These implementation problems are discussed in more detail in Section 4.4.

Benefits were usually more difficult to define than costs. With smaller, stand-alone systems, the benefits were usually fairly obvious and concrete. For example, a firm with multiple robotic installations identified four key benefits: labour savings, reduction in medical costs, improved product consistency with fewer rejects, and increased throughput. Managers have been able to predict within five per cent of accuracy the anticipated savings and expected costs for the robots. However, as the systems become more complex and uncertainty increases, predicting the benefits also becomes more complex. AMT offers entirely new methods for designing and manufacturing products. In an atmosphere of extreme uncertainty, it is often difficult to predict what the returns will be.

Without exception, research participants discussed the difficulty of identifying and quantifying benefits, both tangible and intangible. All of the tangible and intangible benefits listed in Table 2.4, several others, were mentioned by the study participants. While a few respondents attempted to quantify the intangible benefits with estimates or guesses, usually they were simply left out of financial justification. In doing so, the intangible benefits were assigned zero values, making the financial justification more conservative. Listing the intangible benefits on the appropriation form was a universally practised technique and is discussed in more detail below. These results confirm the finding of Rosenthal (1984):

Many leading-edge users acknowledged that it was difficult to quantify all of the expected benefits. A few claimed that "qualitative factors" as improved timeliness, flexibility, and quality were (somehow) incorporated into their calculations. By contrast, most of these users, when pressed, acknowledged

that they left such factors out of the calculations but claimed to account for them in more subjective ways.

As projects increase in complexity and span longer time horizons, not only do the costs and benefits become more vague, but the perceived risks increase as well. Participants were asked if they identified and measured risks for their proposed AMT projects. Only twenty three of the thirty-five firms, tried to identify risks associated with adoption and implementation of AMT. Of these, only five attempted to measure or quantify the risks for inclusion on the appropriation request. A more common approach was to simply list the perceived risks. A middle manager in an aerospace firm discussed his frustration on inclusion of risks on the appropriation request with the politics involved.

We must include the risks as part of the justification. We must identify the probability of the risk of failure. This is really a difficult thing...we have to word it very carefully. We must look at all of the possibilities and what upper management might be thinking. Basically, we are trying to word it correctly in order to get it approved.

Participants emphasised the financial risk of engaging in adoption of AMT. The most frequently cited risk was that the system might fail. If the new technologies did not work at all or were only partially functional, then the ability to ship product was threatened. Performing a benchmark on the equipment before purchase is a common technique used to reduce this risk. Another coping strategy to reduce risk is careful, front-end planning. One firm believing in this approach, spent more than five years in completing the analysis/justification for the proposed advanced manufacturing technologies.

In addition to financial risk, there is considerable additional risk to the organisation. Some of the organisational risks, such as resistance by employees, sabotage of the systems, lack of adequately trained people, are discussed in more detail in Section 4.4. The individuals interviewed were particularly sensitive to "career risk". Even if they are strong proponents of AMT, there could be a fear element that it would not work as expected and create problems. Thus, the tendency to pass the decision of justifying AMT to someone else. However, some participants do have the initiative and drive to justify AMT no matter what hurdles they face. These findings support Dean's (1987) discussion of the "interpersonal component" of the

justification process and Rosenthal's (1984) results regarding the balance between risk and reward:

Our panel of experts generally agreed that the potential rewards available to plant managers tended not to reflect the risks they must take in promoting the adoption of sophisticated programmable manufacturing systems, and that this imbalance creates a significant barrier to such innovations.

As the above examples illustrate, if the expected return or payback period does not meet the required rates established by the firm, then the process becomes more involved. Dean (1987) describes how firms deal with this problem:

The most common approach is for the proponents to exaggerate the benefits sufficiently to meet the hurdle rate... Another approach taken by the proponents is to augment the financial analysis with a rationale based on strategy. This tactic becomes more prevalent as the benefits of the AMT investment become murkier, or as the cost or technical risk increases... In the extreme case financial projections may not be prepared at all and the proponents stake their case solely on their ability to construct a strategic rationale that supports investment in AMT. This approach is probably rare.

All of these approaches were used by firms included in this study. Over 50 per cent of the participants mentioned that if the project was not justified on a financial basis, then you had to "get creative". A production manager in a chemical company stated:

If you could only marginally justify a technology, you can argue your way through the purchase of something like this by talking about image and of other intangibles.

An aerospace company implementing a U.S. \$15 million material distribution handling system described their project proposal:

The capital appropriation is really a PR document...it is much less technical than something I might put together for a machining centre. We have to do this to stay ahead of our close competitors.

Dean predicted that an approach with no financial analysis is probably rare. However, in this study, approximately 25 per cent of the projects justified were without any financial considerations.

The above examples suggest that there is a relationship between the method of justification and the cost of perceived risk associated with the proposed project. As projects increase in complexity and the time horizon stretches, costs and risk increase, making it more difficult to justify using traditional financial investment analysis techniques. If required rates of

return are not met, then non-financial, qualitative techniques are employed to justify the project.

There also appears to be a connection between the method of justification and the reasons for adopting AMT. The firms citing primarily operational or tactical reasons generally were able to apply a financial or quantitative justification methodology. However, firms citing strategic reasons for adopting AMT frequently turned to a non-financial or qualitative justification.

In addition, those projects initiated by top management or a "champion", often circumvented the routine justification process. They were also frequently justified on a qualitative basis. On the other hand, projects initiated from the lower levels of the organisation, typically followed the normal steps in the justification process. These projects usually required a financial justification with acceptable rate of return, or the projects were rejected. Table 4.6 below highlights these three considerations.

In order to understand the difficulties faced by the participants in the justification process and their perceptions of major problems, they were asked the following question: What, if anything posed the single greatest obstacle to the justification of your AMT project? The responses are shown in Table 4.7. Some respondents mentioned more than one obstacle.

TABLE 4.6  
METHOD OF JUSTIFICATION OF AMT

	METHOD OF JUSTIFICATION	
	QUANTITATIVE	QUALITATIVE
COST/RISK OF PROJECT		
High		X
Low	X	
REASON FOR ADOPTION		
Strategic		X
Operational	X	
LEVEL OF PROJECT INITIATION		
Low	X	
High		X



While the obstacles mentioned were expected, the results were somewhat surprising. There were very few obstacles reported, and the order was unexpected. The literature leads one to the belief that the financial analysis techniques present significant problems in justifying AMT. However, the number one concern among the study participants related to management problems.

TABLE 4.7  
OBSTACLES TO JUSTIFICATION OF AMT

OBSTACLE	FREQUENCY	PER CENT
Management Problems	16	46
Cost and Risk	14	40
Justification Techniques	9	26
None	2	6

One of the concerns about management revolved around the difficulty with changes in personnel. Changes in management lead to shifts in philosophy about adopting AMT. A senior manufacturing engineer described his perception of this problem:

There are management changes. Last year we had a new director come in and he can't stand new technology. So, a lot of projects were shelved. It (approval of AMT projects) is very subjective based on current management.

The aerospace firm that originally decided to automate as much as possible and create a state-of-the-art factory has undergone a change in management. As a result, there was a change in philosophy and a number of manual methods are starting to creep back to the factory floor. Once again the willingness to take risks was discussed:

You need a philosophy from the top to automate... There are a lot of risks involved. I think your typical manufacturing engineer isn't willing to take those risks unless there is that top down emphasis that we want to automate whatever we can.

Both of the above examples reflect a more serious, underlying problem: neither firm had a long-range, strategic plan guiding the organisation. As a result, changes in management rippled through the firm and resulted in confusing and conflicting approaches to adoption and implementation of AMT. The second key concern about management focused on the apparent resistance to change by top and middle management. This could be

attributed to the fact that the managers have been there for a long time and have developed resistance to changes.

Another participant's perception of management's arm's length approach to the justification is described as follows:

If the justification is in excess of a certain dollar amount, then it has to go all the way up to corporate. That is when you might start experiencing resistance. The people that are running this particular operation are more familiar with what is going on here. Once it starts to get higher up, they only want to see the numbers coming out right. I don't think they really understand what that thing is going to be used for.

The implication is that top management may throw obstacles in the path of the proponents for automation and either reject proposals or significantly delay justification of proposals for AMT. Delay, could have serious implications for the company as stated by Dean (1987):

... delays allow competitors to implement technology first, thus gaining whatever advantages accrue to the "first mover." Delaying, justification may mean the difference between the opportunity to gain a strategic advantage over the competition and trying merely to regain ground that has been lost.

The cost and risk associated with adopting AMT was mentioned by forty per cent of the participants as an obstacle to justification. AMT is extremely expensive, it becomes more and more difficult to justify these complex systems as the price tag increases. More than one individual noted that investment in AMT is very substantial, starts from a significant base, and is not bounded. Once the firm starts automating, the costs increase as storage capacity is added, systems are interfaced, and so forth:

After ten years there is no way that you could ever go back to the old way of doing things...This type of system does not reduce in cost...it just escalates in cost. It just keeps multiplying and it is very, very costly.

Finally, justification techniques were identified by twenty-six per cent of the participants as posing a significant obstacle to the justification process. The following examples indicate the frustration with conventional investment analysis techniques:

The current methods of ROI. We are not taking into account the intangible benefits and we are not quantifying them.

Showing direct labour savings can be difficult. We must show that we will reduce "x" number of people. Now, labour is 5% of our costs, so it is not practicable. Most of the cost is locked in before it ever gets to manufacturing.

It is true the justification boils down to payback period. There has to be a payback period of 2 or 3 years and if it isn't within that, then it is not approved.

Sometimes I question the value of basing everything on a return on investment. A lot of companies do that and we are one of them. Even though a project does not show a return above the criteria set by the company, the project is still worthwhile. I think that management should start thinking in those directions.

The above statements reflect the perceptions of senior technical staff and middle management. It is quite possible that these individuals were not high enough in the organisation to have an appreciation of the overall picture and may not know the real reasons why projects were rejected. Further interviews with top corporate management may be necessary to confirm the information provided by the respondents. The obstacles discussed above also imply that changes need to take place in the following areas: education for management; reduction in the costs of the equipment; and changes in justification techniques.

The justification techniques currently utilised by the participating firms were perceived as an obstacle to the process of justification. However, few of the alternative methods suggested in the literature are being explored. In fact, only one firm employed a somewhat innovative approach of justification. In this case, all its advanced technology projects, which are seen as critical to achieving the corporation's strategic objectives, enjoy relaxed payback period and ROI guidelines. In addition, these projects were classified as "special projects" and treated more like research and development projects.

By placing these projects in a "special" category, they are excused from the normal post-implementation audits and performance evaluations. The manager in charge is not penalised if overall division objectives are not met as a result of problems with special projects. This approach also reduces the "career risk" for the proponents of the AMT project. In general, this approach encourages management to propose investment in new technology which supports the company's strategic plan. At the same time, it limits their personal exposure, should the project fail. And finally, special projects are reviewed to determine if they are successfully contributing to the firm's achievement of objectives.

In summary, justification of emerging technologies is an extremely difficult and somewhat messy process. However, the difficulties encountered in the

justification of AMT are temporary. These are emerging technologies, with unknown and unproven capabilities.

#### 4.4 RESULTS: IMPLEMENTATION

This section reports on the process of implementing AMT and specifically focuses on how the firms studied managed this complex process. First, the various project management methods and techniques employed by the firms are described. Second, the relationships with groups external to the firm, specifically outside consultants and AMT vendors and suppliers, are explored to understand the positive and negative impacts on the implementation process. Third, a discussion of how the firms handled the difficult task of educating and training employees is then presented. Fourth, both the expected and unanticipated impacts on the organisation are explored, including a review of the perceived obstacles to implementation. Finally, the participants' assessment of the factors critical to successful implementation are reported and compared with earlier studies.

##### 4.4.1 Managing the Implementation Process

As discussed in Chapter 2 there has been fairly extensive coverage of the complex process of implementing planned changes. As with any major project, careful planning and organisation are required when implementing automated systems. As a minimum, standard project management techniques and skills are necessary in order to implement effectively advanced manufacturing technologies. In addition, some special skills and techniques may be unique to implementing AMT versus other major projects. The firms participating in this study were surprisingly homogeneous in their approaches to managing the implementation process. All of them used commonly accepted project management techniques to assist in implementation. Table 4.8 summarises some of the common key elements: (1) selection of a project leader, (2) selection of a project team, and (3) development of an implementation plan.

In thirty-two (91 per cent) of the cases, formal project leaders were assigned or appointed to manage the implementation process. In some instances, this person was the same individual who "championed" the project through the proposal and approval stages discussed above in Section 4.3.1. In the

smaller firms, the champion often plays the role of the project leader (Meredith, 1987c).

TABLE 4.8  
PROJECT MANAGEMENT METHODS UTILISED

RESPONSE	PROJECT LEADER	PROJECT TEAM	IMPLEMENTATION PLAN
Yes	32	32	33
No	0	0	0
Other	2	1	1
Missing	1	1	1

This proved to be true for three of the smaller firms. In the two cases listed as "other", it was not clear from the interview whether one person was formally appointed as a leader of the group or whether the entire project team acted as a unit without a formal leader.

In several rare instances, the project leader devoted all of his time to the AMT implementation. However, it was more common for this individual to continue his normal job responsibilities throughout the project. This finding corroborates Rosenthal's results (1984):

The implementation of computer-aided manufacturing processes often requires full-time project management. For over three-quarters of the projects in the user survey, a manager within the business unit was designated to supervise the implementation effort. However, two-thirds of the time this was not a full-time activity, since the designated person also had other ongoing responsibilities.

Due to the long term nature of these implementations, and complexity, there is an inherent conflict between normal responsibilities and project-related responsibilities. Some participants perceived the preoccupation with daily tasks as an obstacle to implementing effectively AMT projects. This is discussed in more detail in Section 4.4.5.

Numerous studies addressing implementation effectiveness have cited the use of implementation teams with representation from every affected department and area as critical to success (Meredith, 1981; Alter and Ginzberg, 1978). Formal implementation project teams were established in thirty-two (91 per cent) of the cases. That is, key individuals from functional groups throughout the organisation were either selected, or in some cases

volunteered, to participate in the implementation team. Depending on the scope of the project and the type of technology, a project team might have representatives from production control, operations, quality, information systems, cost accounting, and the vendor; and an outside consultant in addition to the project manager. A multi-disciplinary project team was frequently proposed as a way to accomplish two purposes: (1) to make sure the functional/design specifications were complete, and (2) to assist in "selling" employees across the organisation by securing their early involvement and participation in the process. As discussed later in Section 4.4.6, participation and "buy-in" by all levels in a company was perceived to be one of the most critical factors to a successful implementation.

Virtually all the participants emphasised the importance of involving all areas of the company that would be affected by the implementation. Particularly in large scale AMT projects, this translated into fairly large teams since most, if not all, of the functional areas within the firm would be affected in some way. The size of project teams varied, depending on the type of project, stage of implementation, and type of organisation. However, the average size was approximately 8 to 10 members. A firm that eventually halted the implementation of its factory of the future started with approximately twenty people on the project team. According to the manufacturing manager, this was an unusually large team and proved to be "very unwieldy". While it may be desirable to include representation from across the firm, the benefits obtained may be offset by the inability to manage effectively a large group.

One firm did not form project teams for its automation projects. In one instance, a team was assembled early in the proposal and justification phase, in order to determine the needs of and to gather input from potential users of new systems. However, the actual implementation process was managed by one person, the project leader. It should be mentioned that these projects were all stand-alone robots, not extensively integrated systems.

Table 4.9 suggests that the size of the implementation team may have some impact on the outcome of the implementation. This would be worth further investigation to determine if size is a critical success factor.

TABLE 4.9  
PROJECT OUTCOME AND PROJECT TEAM SIZE

PROJECT OUTCOME	PROJECT TEAM SIZE		
	SMALL	MEDIUM	LARGE
Success		X	
Failure	X		X

If the size of the project team was viewed along a continuum, one would expect greater success in implementation with adequate representation from the functional areas of the firm. However, on either extreme, a very small team (eg. only a project manager) or a very large team (eg. twenty members), there may be a significant negative impact on the success of the implementation.

Fossum's study (1986) reported the importance of a stable core of participants on the implementation team, in achieving success. Meredith (1987c) also emphasised the importance of a stable project team:

Automation projects commonly run from 2-5 years and top management must be committed enough to the project to keep this team relatively intact the entire time.

The findings from this study show moderate support for the idea of a stable project team, however, the responses were mixed. A senior manufacturing engineer in a computer firm employing a matrix organisation structure identified problems associated with a "fluid" project team:

One of the major problems is that the people change. So, as a result, the message changes and everyone interprets it differently. Everyone seems to have their own agendas for a particular project. It is especially hard with longer term projects when the players change.

The successful implementation of a materials handling system in another company took over three years. During that time, the project leader, the project team, and the top management did not change. the project leader commented:

Fortunately, there weren't any management changes either. If we had a management change in there, we probably would have had to start from scratch.

Based on the information obtained from this study, it would be very worthwhile to investigate other firms which have failed in their attempts to

implement these technologies. It would be instructive to explore the relationship between stability of the project team with the eventual success of or failure of the project. Table 4.10 displays this suggested relationship.

TABLE 4.10 PROJECT OUTCOME AND PROJECT TEAM STABILITY		
PROJECT OUTCOME	PROJECT TEAM STABILITY	
	LOW	HIGH
Success		X
Failure	X	

Returning to the discussion of project management techniques employed, Table 4.8 shows that thirty-three (94 per cent) of the firms developed implementation plans to guide the organisation in the implementation process. However, the philosophy of using such a tool and the degree of details employed varied across the firms. Some firms strongly believed in a very detailed, carefully prepared plan to guide the company and to anticipate potential problem areas; while many firms saw some value in a very broad-brush implementation plan, but viewed the usefulness of such a tool as being limited. This seemed to be particularly true in the computer industry where the rapid rate of change was viewed as a deterrent to carefully prepared plans.

In addition, some participants noted that management often required a plan, so they prepared a very general plan to appease management. In reality, the plan was not perceived as a viable, working document:

We have been asked to do an implementation plan. It soon falls by the wayside because of change. However, an overall plan is needed. It is needed for management.

Careful monitoring of the project schedule was performed by twenty-six (74 per cent) of the respondents. In twenty-four (69 per cent) cases, the cost was tracked in order to identify any deviation from the allocated project budget. In twenty-one (60 per cent) of the firms, both the schedule and budget were monitored throughout the project.

One computer firm was particularly concerned about time to market and market responsiveness. As a result, the project schedule and timing of the



critical steps of the implementation became the major focus. On the other hand, cost overruns were perceived as minor problems:

We track time more than cost. Staying within the budget is very important, but I think if the issue came up to spending a little bit more money versus slipping the schedule, we would find a way to justify it. The schedule is very important and (the company) works on a very, very aggressive schedule.

A variety of techniques were used to monitor the variables of time and cost. PERT, CPM, Gantt charts, and other various accounting cost reports are examples of the methods used to track progress of the implementation projects. A combination of both manual and automated methods were utilised.

One theme emerged consistently throughout the interviews: the project team typically underestimated the time required to implement AMT. A project manager, accepting blame for their scheduling problems, discussed this phenomenon:

Each phase had its own implementation schedule. I think in every case, we were very optimistic that it would be done a lot sooner. I'd say we were optimistic by about 25%. It always seemed to take an extra four to six weeks to get something finished. That's probably a fault of mine in not coping with the problems successfully to begin with.

Given the fact that these are new technologies and the project teams had limited or no experience in implementing the new systems, one could expect delays in the schedule. According to Meredith (1987c), slippage in schedules translates into cost increases for the firm:

In general, most factory automation projects tend to slip about 100% in their completion times. Unfortunately, major elements of the cost for automation projects are almost directly related to its implementation schedule at a rate of about two to one. Thus, a schedule slippage of 100% can easily translate into a cost increase of about 50%.

Therefore, even though the cost of the equipment may be gradually decreasing, schedule delays, resulting in added time and expense, may offset these reductions. In addition, delays in receiving equipment from vendors and suppliers of AMT, caused further delays and problems in the implementation process. This is discussed in further detail in the next section.

An "as is" study is a careful, realistic review of how the firm actually makes its products and services. The purpose of this type of study is threefold: (1) to

identify existing weaknesses in the firm's production processes and correct them before automation, (2) to identify areas where automation may be most appropriate, and (3) to provide a basis of comparison during the post-implementation evaluation. After preparing a detailed "as is" study, the firm is in a position to develop a "to be" plan which identifies technologies to address the problems and needs identified during the preliminary steps towards implementation of AMT. However, as Meredith (1987c) points out, "as is" studies are generally considered to be unnecessary:

Though usually felt to be unnecessary, almost every medium to large sized firm is surprisingly ignorant of how their product is really made. Employees who know the activities on a task level do not have the breadth to see the overall process, and managers who have the breadth are typically not familiar with individual task elements.

The results from this study confirm that few organisations are performing a detailed analysis of the production process before proceeding with the actual implementation of automated technologies. Less than one-fourth of the firms performed an in-depth "as is" analysis of their manufacturing processes.

Others concurred in that the "length of time" was the most frequent objection to systematically reviewing the existing processes. In the computer/telecommunication industry, time was viewed as a particularly difficult obstacle to performing such a study.

We want to do an "as is" study, but we don't really have the time to do it. Everything moves too fast. It is really difficult, because everything changes in two years. The life cycle of our product is only 18 months. So, if you are implementing some automated system, the products being produced may have completely changed by the time that system is actually implemented and operational.

On the other hand, another computer firm, viewed their thorough front-end analysis of their manufacturing process as vital to their later success with automation. In several cases, where this step is skipped, the organisations later were confronted with major problems during the implementation. One manager of an aerospace firm repeated over and over again during the interview:

You can't automate something that you don't have a process for. You need a reliable process at the beginning.

It is somewhat ironic that so few firms performed an in-depth analysis, however, many perceived an "as is" study as essential to implementation of

AMT. As shown later in Section 4.4.6, understanding the manufacturing process was viewed by the study participants as one of the most critical factors to a successful implementation. Therefore, skipping this key step in the process may very well lead to difficulties or even failures during the implementation process. In addition, failure to understand and document the processes before implementation may interfere with post-implementation evaluation.

In summary, the participating firms were surprisingly consistent in their approaches to managing the implementation process. All of the firms used commonly accepted project management techniques to assist in their implementation. In addition, most of the firms monitored the schedule and budget of their projects. There were, however, major differences in their approaches to preparing an "as is" study or a "to be" study. In general, this study supports the idea that generic implementation approaches and project management techniques are broadly applicable.

The following section continues the discussion of managing the implementation process. In particular, management of external resources, such as outside consultants and vendors, is described.

#### 4.4.2 External Resources

Implementation of advanced manufacturing technologies tests an organisation's ability to skilfully manage all aspects of an extremely long and complex process. Understanding what role, if any, external resources play in the implementation of AMT is important in guiding organisations during this transition phase. The relationships with groups external to the firm, specifically outside consultants and AMT vendors and suppliers, were explored to understand the positive and negative impacts on the implementation process. This section reports on the use of outside consultants by participating firms. The relationship with vendors and suppliers of AMT and their impact on the implementation is also presented.

##### 4.4.2.1 Outside Consultants

The results indicate that outside consultants were used extensively during the implementation process by the participating firms. Table 4.11

summarises the response to the question: Do you use outside consultants in the implementation process?

TABLE 4.11  
USE OF OUTSIDE CONSULTANTS?

RESPONSE	FREQUENCY	PER CENT
Yes	28	80
No	3	9
Missing	4	11

Twenty-eight (80 per cent) of the firms indicated that consultants were used to some degree during the implementation of their AMT projects. The functions performed, however, varied widely depending on the organisation. In some instances, consultants were asked to perform relatively minor functions, such as providing technical assistance on system conversions or programming support. In other cases, consultants were involved from the project initiation stages, and were given full responsibility for implementing the automated systems. Other examples of direct participation of consultants include: development of software, testing of hardware, project planning, education and training, monitoring of project schedules, development of strategic CIM plan, problem resolution and trouble shooting, and system integration and management of multiple vendors.

Twenty of the twenty-eight firms reported fairly extensive involvement of outside consultants. For example, they were occasionally given full responsibility for managing the implementation process. The production manager in a computer firm described this as an ideal situation because the implementation is "project work by nature". Consultants can temporarily fill a void in the organisation, manage the implementation, and then walk out the door. However, an aerospace firm that had used this approach on multiple occasion, ran into serious problems:

We used to hire a lot of consultants and got into a lot of trouble. Some projects were strictly run by outside consultants and we lost control. Now, we do have some consultants helping us, however, most of the work is done in-house.

Another participant pointed out that problems may arise during the transition from the consultant to the organisation at the completion of the implementation:

The biggest problem is when the transition from the consultant to the operation is not complete and because of that, the program falters. I don't really like to use consultants for that reason. I think that at some point in time, the owner has to get involved during the implementation stage, it goes a lot smoothly.

Therefore, consultants are hired to perform a variety of tasks and the context of their involvement varies by organisation.

In addition, multiple consulting groups were frequently hired to perform project-related tasks. Several firms strongly emphasised the necessity of matching the type of consultant with the stage of adoption, implementation, or evaluation of automation:

You have to understand that there are different levels of consulting. As you go from one stage of automation to another, you need to have different consultants. We had four levels of consulting: the strategic planning type, the implementation type with overall knowledge, the consultants that can tune your system specifically, and the auditor, who gives you an impartial appraisal of how you are doing. Some people make the mistake of keeping the same consultant all the way through. It's a mistake.

In the case where outside consultants were not used, the projects were all stand-alone robots, not extensively integrated systems, and the project manager had previous experience with implementation.

Participants were asked to provide additional detail about the positive and negative aspects of their relationships with outside consultants. Table 4.12 summarises the most frequently cited comments. The participants valued the information obtained from consultants, including industry trends, technological advances, and competitive information. In addition, assistance in managing the implementation process was considered a plus. However, participants mentioned problems with some unprofessional, inexperienced consultants with limited experience in their industry. The rates charged by consultants are typically also quite high. One manager referred to consultants as "gold collar workers." Overall, the positive comments outweighed the negative response regarding the use of outside consultants in the implementation process.

#### 4.4.2.2 Vendors and Suppliers

Vendors and suppliers of advanced manufacturing technology are another external resource to the firm implementing automated systems. When research participants were queried about their relationships with their

vendors, the response was overwhelmingly positive. Twenty-eight (80 per cent) of the firms reported a very positive working relationship with their vendors. A theme that emerged from their responses was the reciprocal nature of these relationships. Mutual respect was cited as essential to maintaining a long-term, positive relationship. In addition, the firms viewed the relationship in terms of trade-offs. For example, through a cooperative relationship, vendors may benefit from their client firms as reference sites to test their technologies. Benefits to the client firms include: new product

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TABLE 4.12  
RELATIONSHIPS WITH CONSULTANTS: POSITIVE AND NEGATIVE

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POSITIVE

Manage the implementation process/monitor the schedule  
Share industry trends, information about new technology, competitive information  
Offer guidance based on previous experience with similar systems  
Offer objective opinion/validate internal efforts  
Provide specific technical expertise

NEGATIVE

Inexperienced, unprofessional with limited knowledge of their industry  
Loss of control  
Disagreements and offering opinions  
Prohibitive cost

---

information, competitor information, technical expertise, product enhancements, inputs to new product developments, user training, vendor technical support, and assistance with justification and management presentations.

The findings in this study strongly support earlier research, which emphasised the importance of a strong "supplier-user relationship". (Rosenthal, 1984; Fossum, 1986; and Ettlie, 1986). Ettlie points out the importance of this relationship:

The successful implementation of programmable manufacturing innovation results from the combined efforts of the supplier(s) and the user of the system; they are representatives on a team that is committed to the success of the new manufacturing process. Team-building success within and across organisational boundaries predicts implementation.

As discussed in Section 4.4.1 above, the project team typically includes vendor representatives. In general users tend to rely heavily on suppliers during the implementation stage.

While most firms reported very positive contributions by suppliers to their automation efforts, a number of negative impacts were also felt. Some of the most mentioned problems include: (1) delays in equipment and software delivery, (2) marketing "hype" and pushing/forcing their product as a solution, (3) inadequate technical support, (4) misrepresentation or overselling their product, (5) unrealistic or differing expectations, and (6) difficulties with multiple vendors.

Delays in delivery were common occurrences and one participant commented: "Delays occur nine out of ten times. You manage around it and plan accordingly." Delays resulted in missed implementation deadlines and sometimes caused serious problems for companies on an aggressive schedule.

The stability of the vendor proved to be a serious problem in one or two implementations. An aerospace firm encountered difficulties when the supplier of their AGV's went bankrupt. At considerable expense, they were forced to contract with another vendor to help them complete the implementation.

Problems are frequently encountered when multiple vendors are involved with an implementation, which is almost always the case with integrated AMT systems. Participants expressed frustration in trying to resolve disputes that arose between vendors in trying to interface their equipment:

The only real problem we had to interface the two systems together and they wouldn't interface. They each pointed at the other and said it was the other one's problem. We stood at the bottom of the conveyor and said: "I don't care whose problem it is, you guys fix it". And, they fixed it, but it took us a month.

In summary, the results from this study confirm that firms implementing advanced manufacturing technologies rely heavily on external resources. Outside consultants were used extensively during the implementation process by participating firms. The degree and extent of involvement by consultants varied across the sample firms, ranging from relatively minor technical assistance to full responsibility for project implementation. In addition, the firms emphasised the importance of a strong, positive

relationship with the vendors and suppliers of AMT to the success of the implementation. Although a number of problems were encountered with suppliers, the overall response was extremely positive.

In addition to the functions performed by consultants and vendors discussed above, they play a major role in education and training of employees in firms implementing AMT. This is reviewed in the next section.

#### 4.4.3 Education and Training

Training is frequently stressed as one of the most critical factors for effective computer system implementation. Some authors cite training as the most important factor (Meredith, 1981). It is generally acknowledged that the introduction of AMT may eliminate a number of jobs and dramatically modify responsibilities in others. While some have argued that workers will be "deskilled" and reduced to mundane button-pushing, others argue that the shift in responsibilities for some jobs may demand new skills. In general, it has been predicted that with the introduction of automated manufacturing systems, there will be an increase in mental work and an offsetting decrease in manual work. Armed with this information, management is charged with the task of providing training, retraining, and education of workers who are expected to perform new tasks demanding an increase in mental work.

Education and training are important components of "the human resource strategy" as described by Davis (1986). Ettlie (1986) also notes that "training of properly selected participants in the implementation process is crucial for success." In addition, training is an ongoing process for an organisation implementing AMT. Meredith (1981) views training in the following way:

Training should not just describe the system and explain why it is being installed, but must teach the users how to ask for information and how to use the information they receive. In addition, training must be a continuous process, conducted as new people enter the system. Training sessions should include a "critical mass" of users because if too many people cling to the old system, the new one cannot gain the foothold it needs for successful implementation.

The results of this study indicate that training and education are important components of the implementation of AMT. However, the research participants did not rank training/education as one of the most critical factors to successful implementation. In fact, training was only cited by four respondents as a critical success factor. This is discussed in Section 4.4.6.



Contrary to information presented in the literature, few organisations in this study had a carefully planned strategy to manage the process of education and training for employees affected by the implementation of AMT. Since automation touches almost everyone and extensive change is typically required, it would be expected that education and training would be a major effort. But while firms were not ignoring this issue, very few had devised extensive strategies to deal with it.

In general, organisations relied very heavily on vendors to provide training on using the equipment and systems. Depending upon the type and sophistication of technology, vendor training consists of a broad range of offerings. For example, some provide one or two hours of classes, while others provide a full range of programmes lasting several weeks. In some instances, if the company had a formal training department responsible for ongoing training and education, a member of the training department participated in the vendor training.

There is a potential problem with relying solely on vendors to provide training. As the degree of integration increases, the ability to provide adequate training by single vendors will decrease. In other words, additional training will be necessary to supplement that provided by vendors for their particular systems as islands of automation are linked together. With the introduction of integrated automated systems, the fragmentation and specialisation of job functions will be reversed and individual workers will be responsible for entire operations. Although the participants did not identify this as an obstacle to implementation, nevertheless as firms implement more extensively integrated systems, a more comprehensive training programme, covering interfaces and linkages between systems and processes, may be necessary.

In addition to training provided by vendors, on-the-job training was the most frequently mentioned technique. In most cases, this method was fairly informal. Organisations with training departments generally had developed more formal training for all levels.

The most aggressive and innovative training and education programmes were implemented in the computer and telecommunications industry. In response to the changing job requirements of the workers as a result of

automation, several firms developed extensive training programmes aimed at expanding the capabilities of the workforce:

We have found that we had to raise the expectations and indeed the capabilities of our labour force. To take advantage of their ability, we have trained most of them on the use of personal computers, on statistical analysis and other related issues in management development.

Another firm has instituted a certification programme which links pay with performance. Team members are given nine months to complete a certification process. They must be able to demonstrate the skills and capabilities to perform every operation required to produce their product, from beginning to end. This type of programme allows the workers to have an overall understanding of the process and rewards them for their efforts. In turn, it demands a significant commitment by management to upgrade worker skills by providing comprehensive training programmes.

The participants attached relatively minor importance to the issue of retraining. Virtually all firms participating in the study had a "no layoff" policy related to the introduction of automation. If jobs were eliminated as a result of AMT, workers were assigned different job responsibilities and retrained to perform the functions.

The firms also relied on outside consultants to provide training and education. Typically, the services provided by consultants were directed to conceptual education and focused on middle and top management. While this approach was used in several organisations, it was not common. As reported in the earlier section on obstacles to justification, the lack of understanding and education in top management was perceived as a barrier to adoption of AMT. It is somewhat surprising that more extensive, conceptual education programmes have not been initiated in order to overcome this obstacle. If the need for more education about automation is felt only at the lower levels in the organisation, then perhaps this is the reason why more aggressive programmes have not been implemented.

In summary, the results from this study indicate that training and education are important components of the implementation of AMT. However, the research participants did not rank training and education as one of the most critical factors to a successful implementation. While a number of experimental, innovative training programmes are being introduced by some of the firms, in general, there is a strong reliance on vendors to supply

training for operators. In addition, outside consultants were often retained to provide conceptual education for middle and upper levels of management. This appears to be an area requiring further investigation. Human resource strategies, as proposed by Davis (1986), need to be formulated to incorporate comprehensive training and education programmes for all levels in organisations implementing AMT.

#### 4.4.4 Impact on the Organisation

In order to explore the impact of implementing AMT, firms were asked to describe the ways in which automation caused changes in their organisation. This section highlights some of the changes reported by the participating firms and offers a few illustrative examples. The ideas discussed briefly below are generally beyond the scope of this project, and further in-depth investigation of each of these topics is suggested.

The most frequently mentioned impact on the firm relates to the changing nature of jobs and job responsibilities. Most participants perceived that direct labour employees were given more responsibility and their skills were upgraded. As one manager described this change:

People feel that they are participating more in their job. A lot of people really like that and they are not considered to be "brain-dead" production employees anymore.

In general, the workers' jobs were described as being cleaner, less demanding physically, and more demanding mentally. This confirms the ideas proposed in the literature about shifts in job responsibilities. In addition employees are expected to analyse and solve problems experienced in their areas. One manager in a computer firm stated that "the job of direct labour has changed....we are inviting them to be part of the solution." A shift from specialist to generalist with an overall understanding of the entire process is being experienced by direct labour employees in some firms.

In a number of firms, the participants reported improved morale and job satisfaction, which they attributed to the shifts in job responsibilities. Once the initial resistance to changes was overcome, employees were generally enthusiastic about automation. In particular, if they believed that they were being positively influenced by the changes, a positive attitude replaced the

initial resistance. Further study of this reported improvement in morale is an area for future research.

Formal procedures were modified extensively in virtually all of the firms. Some of the changes related directly to the new equipment and systems implemented, which required a new set of methods and procedures. In addition, some firms reported major procedural changes as a result of simplifying their processes. In many cases, these processes were not automated. The production manager in a computer firm described its process of "understand, document, and simplify" and the impact on procedures:

At the end of the production line, one of our people was filling out a little form with the assembly number, work order number, and quantity. We asked her why she was doing that. She said: "Accounting needs this". So, we took it to the accounting and asked one of the accounting people what they did with it and they said: "Oh, actually we just throw it away, we haven't been using that system for about the last year and a half". But that doesn't get communicated and that kind of thing lives on.

A firm that had implemented a materials handling system reported changes to the entire method of moving and tracking materials on the shop floor. The critical factor with these changes is to document and communicate the new procedures to all affected employees. Once again, additional research is needed to understand how firms are handling this aspect of change.

Implementation of AMT-resulted in significant changes in organisational structures in some of the participating firms. In some instances, entire departments were eliminated or drastically reduced in number of employees as automated systems came on-line. For example, the implementation of an automated warehouse and materials handling system resulted in major cutbacks in the number of materials handlers. However, in most cases, to give confidence in automation to its employees, displaced employees were retained to perform different job responsibilities.

In other cases, entirely new departments or functions were created as a result of automation. For example, one firm pulled electronic technicians from the various product groups and created a team called "Defect Analysis." They were responsible for collecting data on defects, examining the data for trends and for class problems, and resolving problem functions which had never been performed previously. In addition, new career paths were created for these employees. The situation illustrates changes in the

manufacturing process, organisational structure, job responsibilities, procedures and, indirectly in employee morale and job satisfaction.

One aerospace firm implemented physical and structural changes in the organisation. In order to reduce conflicts across functional boundaries and to encourage a cooperative attitude, departments were physically located in the same area and a single senior level manager was put in charge:

We have co-located engineering, tool design, quality and NC people in the same area. We now have a senior director that has quality, production control, MIS and engineering to handle as one function. This has broken down the boundaries between engineering and manufacturing.

Many studies identify lack of cooperation across traditional functional boundaries as a serious deterrent to the implementation of integrated, advanced manufacturing technologies. However, there is evidence from this study that changes are indeed being implemented effectively to manage this problem.

Organisational culture was the last area where firms reported major changes. Many participants perceived that a dramatic shift had taken place in their organisations. In effect, there were shifts in attitudes, beliefs, customs, and rituals that emphasised and encouraged automation. There were reports that employees, who once resisted the introduction of AMT, now accepted change and the use of high technology equipment. In general, a gradual but definite change in culture was experienced by virtually all firms.

#### 4.4.5 Obstacles to Implementation

In order to understand the perceived obstacles to implementation, participants were asked to respond to the question: What, if anything, poses the single greatest obstacle to implementation? The responses are summarised in Table 4.13. Some participants indicated more than one obstacle.

The response to this question is notable because it confirms the idea proposed in the literature that managerial rather than technical problems often present greater challenges to the organisation implementing AMT. Two out of three major obstacles identified by the firms participating in this

study were managerial. However, it should also be pointed out that technical concerns were viewed as presenting major challenges to implementation.

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TABLE 4.13  
OBSTACLES TO IMPLEMENTATION OF AMT

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OBSTACLE	FREQUENCY	PER CENT
Resistance to Change	14	40
Technical Problems	11	31
Lack of Effective Project Team	6	17
Other*	4	12

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\*Other includes: design for flexibility, training, union involvement, incremental implementation, vendor-user relationship.

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The most frequently cited obstacle to implementation was resistance to change. Fourteen (40 per cent) of the respondents reported resistance to change at all levels within the organisation as a significant problem in the implementation process. People are not automatically resistant to change. However, they resist change for a reason: when they perceive the consequence as negative. Implementation of automation causes major change throughout the organisation and there are a number of possible reasons for opposition to these new technologies. For example, common reasons for resistance to change include: fear of the loss of skills, fear of the loss of power, and absence of an apparent personal benefit. All of these reasons were offered by participants as explanations for resistance to change in their organisations.

A production manager in a chemicals firm described the attitude in his organisation:

We have been here for a long time and people are used to doing things the "same old way". There was a lot of inertia. There were a number of people who said: "Wait a minute, we are a successful company, we have a reputation for high quality, we are still growing fast, and so on. So, why change? What's broken?" I think that was the main barrier.

A number of participants noted that perceived loss of power resulted in resistance to change, particularly in the ranks of middle management. Although the reduction of direct labour has been widely publicised and anticipated, the reduction of middle managers has received less attention. In an aerospace firm this problem was particularly acute:

The problem has been with middle management. The manpower reduction has been the hardest to sell. It has to do with power. It affects people and their "army" of people. I am taking away the old, traditional forces and people don't like that. We expect that their number will diminish. I think that about two out of three will be eliminated.

Resistance to change can manifest itself in a number of different ways. A number of sites described efforts by workers to sabotage the system or "work around" the automated equipment in order to render the automated tracking useless. Similarly, the lack of acceptance of "buy-in" by the people in the firm was perceived as a major obstacle and resulted in resistance to change. In the aerospace industry, one manager flatly stated:

If you don't have user buy-in ahead of the start of the project, forget it. The project is sure to fail. It must be most or all of the users, not just one or two of them. If the user doesn't want it, he can make it fail. Both management and users must want it.

Technical problems were mentioned by eleven (31 per cent) of the firms as a major obstacle to implementation. Several firms experienced serious problems by rushing into full-scale production before all of the bugs had been resolved with the newly implemented system. This problem frequently resulted in missed shipments and possible morale problems as workers struggled with malfunctioning equipment and software. Several commented that if they had taken more time on the front-end to resolve the problems, they would have been spared serious problems later in the implementation. The operations manager in a machinery firm described the difficulties:

Try debugging something while you are supposed to be doing production off it. You never get it right. The last thing you want to do is bring in a piece of equipment that is only running 50 to 60% efficiency. You have got to be sure you are bringing in equipment that has been debugged as much as possible.

A senior, manufacturing engineer also commented about the technical difficulties encountered with their laser equipment:

Make sure that it works before you put it into production. We didn't. It is a custom built and custom designed machine... and you are working with a complicated product with over 450 variables. You just have to give yourself more time.

Six (17 per cent) of the firms reported the lack of an effective project team as a significant obstacle to a successful implementation. Participants cited difficulties with unclear and changing expectations about the overall project. In addition, poor communication between team members was identified as a serious concern. Communication problems in some cases were attributed to

difficulties in crossing traditional functional boundaries. In several instances, problems resulted from the lack of stability of the project team, as discussed in an earlier section:

The biggest obstacle is the lack of understanding from the operators to the business managers to cooperate. We need to have a clear set of expectations up front. We should have a meeting with all of the involved people and state: These are the expectations for this project. Then we all need to agree on those expectations.

Other obstacles mentioned included: design for flexibility, training, union involvement, incremental implementation and vendor-user relationship. Although these obstacles were expected, it is somewhat surprising that some of them were not mentioned more frequently in this study. In particular, it was expected that training and supplier-vendor relationship would pose more serious obstacles than those indicated here. However, these results are consistent with the earlier discussions in Section 4.4.2 and 4.4.3 about external resources and education and training.

In summary, participants identified three major obstacles to their implementation efforts: resistance to change, technical problems, and lack of an effective project team. Two out of the three major obstacles identified by the participating firms were managerial. Technical concerns were also perceived as major challenges to implementation.

#### 4.4.6 Critical Success Factors

Researchers have attempted to identify underlying factors critical to implementation success, with the purpose of identifying an important set of characteristics or factors which might significantly improve the successful implementation. If a causal link could be established between the independent variables or set of factors and the dependent variables, then an implementation strategy could be developed emphasising the independent variables. As established in Chapter 2, there is a lack of consensus regarding a single set of factors which might improve the successful implementation or what constitutes a successful implementation. However, a number of factors consistently emerge in the literature.

In order to extend earlier studies regarding critical success factors (Lucas, 1982; Meredith, 1981; Ginzberg, 1981; and Ettlie, 1986), research participants were asked to identify the three most critical factors to a



successful implementation of advanced manufacturing technologies. Table 4.14 lists the responses rank-ordered by frequency of citation.

Overall, the results from this study corroborate the findings of earlier studies. Meredith (1981) points out that "actually only about a dozen factors consistently emerge in the literature", which is approximately the number of factors identified by the participants in this study. The factors reported in Table 4.14 are generally consistent with those discussed in the literature, however, the order of importance (associated with frequency of citation) differs. In particular, these factors are comparable to those identified by Ettlie (1986).

TABLE 4.14  
CRITICAL SUCCESS FACTORS

FACTOR	FREQUENCY	PER CENT
Project Management	21	60
Participation	15	43
Understand Manufacturing Process	9	26
Incremental Implementation	8	22
Properly Functioning Equipment	6	17
Strategy	3	9
Vendor Relationship	3	9
Other*	2	6

\* Other includes: integration, justification, communication, training

The most frequently mentioned factor that accounts for success or failure in implementation of AMT was project management. Twenty-one (60 per cent) of the firms noted the importance of detailed implementation planning, careful selection of the implementation team, and proper management of the implementation process. Participants discussed the importance of setting fixed milestones and realistic target dates. In addition, monitoring the schedule was perceived as important to the process. Three respondents specifically discussed the impact of timing on the implementation process. For example, plant shutdowns, holidays, or business slowdowns were perceived as the most appropriate times for "going live" with new technologies. But only a few firms planned their implementations to coincide with these events. However, most admitted that this was generally possible. This result is not particularly surprising, since most participating firms employed typical project management techniques, as discussed in an

earlier section. However, it is somewhat unexpected that this was the most frequently mentioned factor.

Participation was mentioned as a critical success factor in fifteen (43 per cent) of the cases. This factor is a combination of the two most commonly cited variables in the literature: top management support and participation of the users in the design and implementation process (Ettlie, 1986; Meredith, 1981). Participants stressed the importance of involvement and participation from all levels within the organisation, including top management down to users. The notion of "selling" the system to all levels and getting "buy-in" by everyone was considered to be very important. Ettlie (1986) points out that participation is often used as a method of overcoming resistance to change. As discussed in Section 4.4.5 such, resistance was identified by the participants as one of the greatest obstacles to implementation. Therefore, it is not surprising that this factor was considered to be of critical importance in the overall success of an AMT implementation. In general, this corroborates earlier studies which consistently correlated user participation and management involvement with implementation success.

Understanding the manufacturing process was mentioned by nine (26 per cent) of the firms. Performing a detailed analysis of the production process (eg. an as-is study) before proceeding with the actual implementation of automated technologies; was identified as a factor critical to successful implementation. As noted in the discussion in Section 4.4.1 above, less than one-fourth of the firms in this study performed such a detailed analysis of their production process. Skipping this key step in the process may lead to difficulties or even failure during the implementation process. In addition, failure to understand and document the process before implementation may interfere with post-implementation evaluation. This factor is related to Ettlie's "product-process dependency".

Incremental implementation strategy was identified by eight (22 per cent) of the firms as an important factor in a successful implementation. This confirms Ettlie's (1986) findings:

Don't try too much too fast. It is wise to take a strategic approach to phased adoption and implementation for these major, multi-machine, multi-control systems. Allow sufficient time to implement.

Many of the participants interviewed described their frustration with diving into a project that was much too large and complex to effectively manage, especially since they had limited or no experience with the new technologies.

An incremental, phased implementation implies that there is some overall technology strategy guiding the organisation in its adoption and implementation of AMT. Strategy was also mentioned in a number of instances as a factor critical to a successful implementation. This variable supports Ettlie's earlier study. Participants noted the importance of having a "vision" of the overall project and clearly defined goals with a long-range planning horizon. This factor supports the earlier discussion about the importance of manufacturing and technology strategies for adoption and implementation of AMT.

Six (17 per cent) of the firms reported the importance of properly functioning equipment before "going live" with an implementation. In other words, several firms experienced serious on-going problems when they rushed to begin production with their newly implemented systems without careful debugging. Although this factor does not match any proposed by Ettlie, it might be considered a "technical factor" in Meredith's (1981) classification scheme.

Ettlie's study (1986) found that the most frequently mentioned factor was a strong supplier-user relationship. As discussed above in Section 4.4.2, the firms included in this study viewed their relationships with vendors as very positive. However, when questioned about factors critical to a successful implementation, only three (9 per cent) firms mentioned the importance of a strong vendor relationship. A possible explanation of this may be that most firms enjoyed fairly positive relationships with their suppliers and did not consider this a serious problem. It is also possible that the participants may have interpreted the question to relate only to factors internal to the organisation. All of the other issues identified had an internal focus.

Finally, only two firms (6 per cent) mentioned training as a factor critical to a successful implementation. This result is unexpected, considering the importance and difficulty of educating and training members of an organisation undergoing such a major transition. However, this result

supports the view of the firms' apparent "laissez-faire" approach to training reviewed above in Section 4.4.3.

Other variables mentioned by only one firm included: integration, justification, and communication. Each of these factors support Ettlie's reported factors, including: computer integrated manufacturing, justification, and human resource strategy.

In summary, the results from this study confirm most earlier research on critical success factors. The four most frequently mentioned factors considered important to a successful implementation are: project management, participation, understanding the manufacturing process, and incremental implementation strategy. Although the order of importance (frequency of citation) does not match precisely Ettlie's results, the range of critical success factors is consistent with earlier studies.

It has been shown that the implementation process is fairly complex and difficult to manage. Respondents identified significant impacts on the organisation and numerous obstacles to effective implementation. In addition, factors considered to be critical to a successful implementation were identified. The next section presents an overview of the process of evaluation, and indicates that the ability to identify a successful implementation is hampered by limited retrospective evaluations performed by organisations implementing AMT.

#### 4.5 RESULTS: EVALUATION

As discussed in Chapter 2, follow-up evaluations were expected to be of primary concern to top management, yet review of the literature reveals that careful and accurate post-implementation audits are rarely performed in industry. This section reports on the post-implementation evaluation of advanced manufacturing systems. First, the degree of satisfaction with AMT of the participating firms is discussed. Second, the benefits achieved by these firms from AMT are presented. Third, the process of formal evaluation used by these firms is examined. Finally, a discussion of the perceived obstacles to formal evaluation of AMT systems is presented.

#### 4.5.1 Satisfaction with AMT

Success in implementing automated technologies has been limited and there are reports that many implementations have resulted in failure. In order to understand the participants' perception about their automated technologies, they were asked to respond to the following question: Are you satisfied with your factory automation systems? They were asked to rate their satisfaction on a scale of 1 to 5. The responses are summarised in Table 4.15.

TABLE 4.15  
SATISFACTION WITH FACTORY AUTOMATION SYSTEMS

RESPONSE		FREQUENCY	PER CENT
1	Very Dissatisfied	0	0
2	Moderately Dissatisfied	2	6
3	Satisfied	14	40
4	Moderately Satisfied	12	34
5	Very Satisfied	7	20

The response to this question was somewhat surprising, given the reports in the literature. One might have expected the response to cluster at the extremes of the scale, meaning that participants were either very dissatisfied or very satisfied with their systems. However, none of the participants indicated extreme dissatisfaction with their factory automation systems. In fact, 94 per cent of the firms rated a three or better, meaning that the participants were generally to very satisfied with their AMT systems. The average response was 3.7, indicating a slightly above average satisfaction with their implemented systems.

There are several possible explanations for these responses. Individuals who played a major role in adopting and implementing these systems might have been expected, to positively bias their response. That is, they may tend to exaggerate their success and downplay their failures. As discussed in Chapter 3, steps were taken to avoid this bias, however, it is quite possible that some responses were biased in this fashion.

One other possible explanation relates to the manner in which the question was presented. The participants were required to rate the overall factory automation system. There was a tendency to apply a rating to each

individual technology, rather than to the whole system. Therefore, the response would have a tendency to cluster around the mean, as the participants averaged across all systems.

When the participants were asked to explain their responses, several patterns emerged. First, for those not totally satisfied, there was a feeling that even though progress had been made, much more remained to be accomplished. Second, others expressed concern that it was simply too early to evaluate their systems since they were still in the process of implementation.

In cases where the participants were very satisfied, they emphasised that the systems were performing to expectations, people in the organisation were saying positive things about the automated technologies, and the systems worked.

In summary, the participants seem to have been moderately satisfied with the implementation of their advanced manufacturing technologies. The general perception being that progress has been made in the implementation of AMT, but much work still remains.

#### 4.5.2 Benefits

Following up on the level of satisfaction expressed with respect to their advanced manufacturing systems, the research participants were asked to enumerate the benefits achieved from implementing their AMT projects, which involved one or more of the three categories: design and manufacturing process (eg. CIM), quality management (eg. TQC), and production planning and control (e.g. JIT). As expected, the list of benefits is long and varied and is somewhat dependent upon the type of technology implemented. Table 4.16 lists the benefits claimed by the participants. This table is a combination of the proposed benefits and the reasons for adoption presented earlier. Improved quality was reported by all the participants. This relates to the response from the background questionnaire in Appendix I. Participants state that the lessons learned from manufacturing in the last five years include the importance of quality and overall cost reduction.

The literature reports that synergistic benefits accrue to users of AMT, particularly as various systems are integrated. Twenty-two (63 per cent) of

the firms believed that they had gained synergistic benefits as a result of implementing their automated manufacturing systems. As expected, most of the "yes" responses were concentrated in the computer and telecommunications industry, the most highly automated and extensively integrated of the industries included in the sample.

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TABLE 4.16  
BENEFITS ACHIEVED FROM IMPLEMENTING AMT

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BENEFITS	FREQUENCY	PER CENT
Improve Quality	35	100
Improve Productivity	32	91
Reduce Manufacturing Costs	32	91
Reduce Labour (direct/indirect)	30	86
Reduce Inventory	30	86
Reduce Cycle Time	29	74
Increase Capacity/Expansion	25	71
Market Perception and Image	25	71
Improve Morale	20	57
Upgrade Technical/Supervisory Skills	18	51
Improve Safety	15	43
Maintain/Improve Competitive Edge	14	40
Leading Edge of Manfg.Tech.	12	34
Lower Labour Turnover	10	29
Other*	4	11

\* Other Includes: improved control, better communication, better management information..

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The synergistic benefits reported were varied, often unanticipated. One computer company noticed improved communication between research and development as a result of implementing its CAD/CAM system. In addition, integration of its MRP system with automated materials handling systems streamlined and automated many cost accounting, material tracking, and inventory management functions. An aerospace firm also noticed marked improvements in working with a common database. For example, engineering change orders were updated once, rather than five different times in five separate databases. As a result, data integrity and accuracy improved. The following comments provide further examples of perceived synergistic benefits:

It forces people from different backgrounds to work together and to get an understanding of each other's point of view... that in and of itself, buys something. Also, when you work with somebody on one project and it is successful, it folds over into other areas as well. You build up mutual respect.

As you do things, you realise you can do more. We have paved the road for change in the future. We couldn't have changed as fast as we have without some of these systems. Also, we are able to give management information that they didn't have before.

This last comment supports the notion that implementation of AMT acts as a catalyst for change in an organisation (Meredith, 1987e).

As shown in Section 4.5.3, very few participants conducted formal, post-implementation evaluations of their automated systems. As a result, the benefits listed above are generally subjective and reflect the perceptions of the participants. In general, the ability to confirm or deny the proposed benefits associated with AMT is limited, given the fact that implementors have not undertaken comprehensive evaluations.

Relating the level of satisfaction with the lack of formal evaluation of benefits achieved may explain why participants indicated fairly "middle of the road" responses when asked to rate their degree of satisfaction. In effect, without measuring and quantifying the benefits achieved, it cannot be stated with any degree of certainty whether the implementation was a success or a failure. The following section discuss formal post-implementation evaluations.

#### 4.5.3 Formal Evaluation

The results from this study corroborate the findings of Rosenthal (1984) and Fossum (1986): comprehensive retrospective evaluations of AMT projects are rarely performed. Table 4.17 summarises the responses to the question: Was a formal evaluation performed on your AMT systems?

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TABLE 4.17  
FORMAL EVALUATION OF AMT SYSTEMS

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RESPONSE	FREQUENCY	PER CENT
Yes	15	43
No	20	57

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About 60 per cent of the firms had not performed a formal evaluation of their advanced manufacturing systems. The "no" responses were distributed across all industries included in the sample. In order to understand the "no"



responses, participants were asked to explain in more detail. Some indicated that top management did not require an evaluation, therefore, one had not been done. In other cases, the individuals claimed that a formal evaluation was not necessary, since it was possible to see how things were going.

In general, people believed that if a formal evaluation was performed, it would not provide a lot of information due to changes in the system, the products and the environment. In the rapidly changing computer industry, one manager described his frustration:

We haven't really done a formal review of the benefits that we anticipated. I can't answer you in numbers. A success or failure is very disguised because the environment is constantly shifting. It is almost sad... you wish things would stay the same, just so you would know whether or not the project worked. You never know. But, I think the general feeling is that we have been more right than wrong.

The responses were generally vague. In several cases, participants were surprised by the question, as if they had never even considered the idea of performing a post-implementation audit. Given the fact that many of these projects cost millions of dollars, the overall lack of concern about a follow-up evaluation is somewhat unsettling. An aerospace firm included in the sample has been in the process of implementing a highly automated factory for the past five years. One of the managers admitted that there is no evaluation system in place and even if there is one, it was simply too early to evaluate. Panisset (1988) appears to be right on target with the observation that, "if we don't measure the business, we don't know if we have finished implementing and, as a result, we may never evaluate the benefits derived".

Forty-three per cent of the firms performed formal evaluations on their AMT systems. In each case, the anticipated returns proposed in the project justification were compared with the actual returns. In two organisations the process was very formal and the evaluation was performed by the firm's internal auditors. The plant manager of a machinery firm, described its process:

A year later, after the implementation is started, the auditing department will do an audit to see where they are. If they see something that looks like it is really unreasonable, they may call me in and say: "Can you tell me why they have this kind of problem? Did they really take into account everything they should have on the appropriation?" That helps us, in fact, for the next appropriation.

This confirms the idea advanced by Clark, Hindelang, and Pritchard (1984) that post-implementation reviews may provide management with more complete information that should prove helpful in reviewing and justifying similar projects in the future. Considering the lack of experience with these new technologies, this would seem to be especially helpful.

Two of the computer and telecommunications firms that performed a formal evaluation, conformed exactly to the five step process proposed by Panisset (1988).

1. Define measures of the business.
2. Determine initial values of those measures.
3. Set targets for those measures after implementation.
4. Track values of those measures during/after implementation.
5. Compare those values with the targets.

They identified both management and operational measures to be tracked. In addition, they allowed researchers to survey the employees after the implementation to gather information about the workers' perceptions and attitudes.

In some cases where a post-implementation audit was performed, a quantitative, financial justification had been used to justify the investment in AMT. Therefore, it was possible to compare projected costs with actual costs; projected benefits with actual benefits; and to calculate the actual returns from the project. Regardless of the method of justification, it is possible to evaluate the implementation of AMT systems to determine whether objectives have been achieved. In general, the task would probably be easier if a financial, quantitative justification was prepared, however, evaluation need not be limited to such cases.

#### 4.5.4 Obstacles to Formal Evaluation.

In order to understand why firms were not performing post-implementation evaluations and assessing the perceived obstacles to evaluation, participants were asked to respond to the question: What, if anything, poses the single greatest obstacle to evaluation? The response to this question was notable because all of the participants responded with the same general observations. Two general themes ran throughout the responses. First, they believed that evaluation was not possible because key metrics were either not recorded or did not exist before the implementation process

began. In other words, the "before" data could not be compared with the "after" data. This again supports the findings of Rosenthal (1984):

Comprehensive retrospective evaluations are difficult to perform, and are often technically infeasible. The essence of such evaluations is to compare the performance of a manufacturing process before and after a factory automation project is implemented. Frequently, the required "before" data do not exist at the desired level of detail.

Several of the participants' responses further illustrate this point:

The biggest obstacle is not establishing your metrics and then trying to go back six months to a year or two years later and figuring out whether you have made any improvements.

The second major theme focused on the perception that the ever-changing nature of the business and the impacts of the AMT implementation on the organisation made it infeasible to perform a post-implementation evaluation. In addition to the above mentioned obstacles, the difficulty of measuring intangibles, as discussed in the section on justification, resurfaces in attempts to evaluate these systems.

In summary, a limited number of formal comprehensive evaluations are being conducted. Reasons offered by the sample firms include:

1. Formal evaluations are usually not required by top management.
2. Formal evaluations only serve to reconfirm what is already obvious.
3. Due to the shifting environment, it is not possible to perform evaluations.
4. Absence of detailed "before" data makes evaluations technically infeasible.

Given the fact that 43 per cent of the firms were able to evaluate successfully the performance of their systems, it is pertinent to question the reasons offered above and view them simply as objections. It is quite plausible that the individuals responsible for the justification and implementation are unwilling to perform a post-implementation audit because they suspect less than desirable results. In effect, they are shielding themselves from possible repercussions, should the results not match the initial claims stated in the justification.

In addition, it is certainly possible that lack of discipline and resources to collect and analyse the data may play a major role. Not only must the specific performance results be identified, but a method must be devised to measure and analyse them. As Rosenthal (1984) points out:

The ability to measure impacts... typically requires the allocation of significant resources towards that end. It remains to be seen, however, to what extent this kind of measurement activity becomes a priority for corporate management.

The results from this study indicate that comprehensive retrospective evaluations are not yet a priority for corporate management.

#### 4.6 RESULTS: ISSUES IN MANAGEMENT OF TECHNOLOGY

Technology plays an important role in present and future costs and quality of the product. Historically, there has been a time lag between the development of technology and its application. In today's competitive environment, one of the biggest challenges facing corporations is reducing this lag. The general view of the firms participating in this study is that, to be able to do so, technologists must understand the key issues in business management and business strategy, and business managers must understand the key issues in technology management. This two-fold understanding facilitates achieving the desired results from technology to enhance business performance. The most important measures of business performance were identified as profitability level, generating increased sales, and creating new opportunities and facilities.

This section reports on how firms manage the development and use of technology. From the case studies a very interesting pattern emerges. Most participating firms are still paying more attention to the processes of the adoption, justification and implementation of AMT. One of the reasons for this could be that many firms were at various stages of using AMT. Though they anticipate the benefits from AMT, they are not fully ready to further exploit technology, include it in their business strategy and integrate it with manufacturing operations.

Among the participants, only a handful were concerned with the management of technology. This is shown in Table 4.18. This question was more relevant to three people within most firms: the top manager of research and development, the top manager of manufacturing and the plant manager. The other people were more involved in functional roles or projects and were not in a position to comment or give more detailed explanations of this issue.

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TABLE 4.18  
CONSIDERATION OF WIDER ISSUES IN MANAGEMENT OF TECHNOLOGY

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RESPONSE	FREQUENCY	PER CENT
Yes	20	57
No	11	31
Missing	4	12

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Of the fifty-seven per cent of the firms which consider the wider issues in management of technology, most of the responses came from the computer and telecommunications industry. The reason could be that this sector is in a very competitive environment, which requires products to be introduced in the market rapidly with better features and innovations. The product life cycle in this sector is also reasonably short when compared to other industries. Some firms within the automobile sector also showed a concern in this area. In the course of interviews a host of ideas were discussed, which illustrated the link between technology and manufacturing, use of technology and its strategic implications for business. Though this is a new area and participants have limited experience, what follows is an attempt to capture some of the highlights of the discussions to amplify these technology management issues in industry. The topic was debated along three major lines: strategy, time-based competition and outsourcing of technology.

#### 4.6.1 Strategy and Technology

The interviews revealed that a combination of technological-push and market-pull (Munro and Noori, 1988) considerations occurs when management engages in more of a matching process between the means provided by the new technology and the need to address particular deficiencies or to capitalise on identified opportunities in the market. This shows why the business strategy of the enterprise should be integrated carefully with the technological issues. The manager of R&D of a computer firm suggested in one interview that:

The CEO should be well advised to make time for keeping up with technical developments, in order to assess properly the risks and advantages of a given techno-economic alternative. He must also have the long term perspective in securing the appropriate competence-base for the future of his firm; this includes protecting the mavericks who are the repository of knowledge critical to the company.

A participant from a leading automobile firm cited an example to show how early a company must identify a key opportunity and go into partnership in order to have the option to play the game later. In this particular case, the electric car being assessed as a key area for the manufacturer's future, the firm has made a considerable long-term investment in constituting a car designing team in cooperation with a steelmaker in developing novel approaches to using steel in the body and chassis of light-weight battery powered prototypes.

The interviews showed another growing concern to identify key technological issues of current importance and how these issues could be incorporated in the final product in the future. For example, how to incorporate concern for the environment into the strategy of the firm and its product. A plant manager at a chemical firm clearly stressed this pre-occupation, as his company's decision to voluntarily phase out CFC production is only one attention grabbing decision amongst numerous others. He said:

The ecological dimension must be injected at the very beginning of the design phase of new products or processes. In this area however, decision-tools need to be developed to assess realistically the impacts over the entire lifetime of the product, from processing to usage and to disposal, recycling or re-use.

#### 4.6.2 Time-Based Competition

The time-to-market issue was singled out as absolutely critical, imposing new ways of organising, as well as of exploiting information technology. It requires productive communication and effective teamwork between R&D, marketing, and manufacturing, so as to calibrate constantly the ongoing development with the perceived wishes of the customer and the demands of high quality, low-cost manufacturing. Such teamwork sometimes termed "concurrent engineering", encounters many barriers; this is particularly true when company fragmentation into business units destroys any common platform for justification of supporting mid and long-term developments.

Forced upon companies by fierce world competitive pressures and by increased power in the hands of the increasingly demanding and volatile customers, time-based competition points to bringing innovations to market effectively and rapidly. A participant from the computer industry said:

It hurts more by introducing the product late to the market than by overshooting the product development budget.

Another major challenge for companies in the 1990s is to manage product and process development more globally. Indeed, in spite of all the talk about internationalisation, most multinationals still carry out 90% of their R&D in their home countries. Global technological development requires vigorous communication flow between various factors involved; by all accounts, software development is the application here. This specific need was noted from the people connected with information systems.

A strong integrating force in the race for achieving shorter time to market and customer seduction is design management, which connects early in the process with a multitude of inputs from different horizons within the company. A manager from a computer firm presented convincing arguments in favour of a growing integrative role of design in the development of new business. In the future, computers and electronic navigation systems will be used widely in cars. Thus car makers, and computers and electronics companies are particularly active in differentiating their products by the quest for the "intangible" that will trigger the client's purchasing decision. Flexible manufacturing also impacts on the work of the designer in that he must produce more variations of designs, while these are introduced in production with shorter lag-times.

#### 4.6.3 Outsourcing of Technology

Outsourcing of technology development was another topic of importance to the participants. Firms are no longer able to master alone the broad front of technical and business know-how required to achieve success in the fast-paced, complex, world market-place. They must therefore reach out and tap external providers of technology, but also collaborate with the extended family of the firm, customers and suppliers, as well as with competitors, as is the case between the alliance of two computer manufacturers in this study which undertake joint R&D in developing new components. One of the leading chemicals manufacturers interviewed is involved in several hundred collaborations, which accounts for close to one-third of its total R&D effort.

The idea of the supplier having to "seduce" the customer at an early stage with its technological prowess came when the director of R&D of a computer

and telecommunications firm that also works with banks in automated money transactions said:

The client, bank, chain of gas stations, etc. chooses the supplier who brings maximum value, quality of service and reliability; it then co-develops, with the supplier the complete automated money transactions system.

The management of ventures involving transnational, multi-organisations of various cultures, introduces new degrees of complexity, as shown by the alliance of two computer and telecommunications firms, where both companies fully cooperate in product development and manufacturing, but fully compete to sell their final products in automated banking in the market-place: firms need to learn to deal with their dual roles in collaborating in product development, while also competing in the market-place.

At the end of the outsourcing chain is the firm using technology, such as Information Technology (IT). For banks, insurance companies and airline companies alike, indeed the service sector as a whole, IT is central to their strategy and organisation, and in providing value for their customers. A vivid example was given by a computer firm which also provides information technology services to a transportation company:

The challenge of real-time tracking 1.5 million packages, transported daily by a fleet of 433 planes and several thousand lorries, hinges totally on an advanced and powerful computer/telecommunication system.

This study demonstrates the steadily growing interest of firms in the integrative, communication intensive tools of technology management. Today, firms are dependant on external vendors and suppliers for their technology and other critical parts which sometimes require mutual technical developments. Firms not only have to implement AMT to improve manufacturing operations, but at the same time must continuously translate new technological advances both internally mastered and externally developed with their existing operations. This explains why some innovative firms recognise and seize upon technology-based opportunities, and incorporate these into their manufacturing processes better than others in order to become more competitive and successful.

In summary the strategic management of technology takes into consideration short and long-term corporate objectives and translates them into an action plan. The planning process is carried out in concert with strategic business planning and considers the need and constraints of both



the business and technology. Technology management's central challenge is, therefore, to respond effectively to the growing complexity of assembling sub-systems, while retaining flexibility.

## **CHAPTER 5**

### **RESULTS OF QUANTITATIVE ANALYSES**

#### **5.1 INTRODUCTION**

In the previous chapter, the experiences of participating firms in the management processes of adoption, implementation, and evaluation of AMT were presented. Some key issues in technology management pertaining to AMT were also explored. The results emerging from the first phase of qualitative case analyses of this study indicate that the reasons for adopting AMT were essentially to achieve better performance in manufacturing. Firms identified both individual and synergistic benefits in cost, quality, delivery, and flexibility from the application of these technologies. The results also indicate the importance of incorporating technology management issues while formulating business strategies. To explore the above issues further, a detailed quantitative study of the same firms was conducted using the methodology discussed in Section 3.3. This chapter presents the results of that study.

Section 5.2 analyses the reliability of all the measurement scales used, and the construct validity of these measurement scales are examined in Section 5.3 using factor analysis. Section 5.4 presents the results of multiple regression analysis of the effects of application of AMT on competitive performance measures in manufacturing, and the hypotheses formulated in Section 3.3.5 are tested here. Section 5.5 describes, through an analysis of criterion validity, the interrelationships between the management processes of adoption, implementation and evaluation of AMT with the competitive performance measures in manufacturing, and implicitly tests the hypothesis formulated in Section 3.3.6. A similar analysis of criterion validity is used to investigate the effects of the proposed factors of effective management of technology on the performance factors at the business unit level. In addition, a correlation analysis is performed to explain the varying impacts of the firms' response to new technological developments. The firms are classified as "opportunistic/proactive" or "defensive/reactive", based on its response to new technological developments. The results of these analyses are given in Section 5.6.

## 5.2 RELIABILITY OF MEASUREMENT SCALES

In order to determine their ability to yield consistent measurement, a reliability analysis of the measurement scales was conducted. Different forms of reliability assessment, such as test-retest, alternative forms, and internal consistency, were considered. Because the subjects would probably not have participated in the repeated administration of the survey, reliability was operationalised as internal consistency.

In order to determine internal consistency, Cronbach's alpha was calculated for each scale (Cronbach, 1951). Coefficient alpha is, to a first approximation, the average correlation coefficient of each item with each of the other items in the scale (Nunnally, 1978).

Many researchers agree that a Cronbach's alpha of 0.7 is considered an adequate level of internal consistency (Nunnally, 1978). For research using new scales, like this study, Nunnally suggests that an alpha value of 0.6 would be acceptable. Other researchers accept a lower alpha value. Jones and James (1979) claimed that their scales, with alpha values from 0.44 to 0.81, provided an acceptable measurement instrument, because of the smaller number of items in the scales. A conservative limit set for alpha for this study was 0.6.

The reliabilities of the scales are shown in Table 5.1 for the various measures of constructs. The Cronbach's alphas for the scales in CIM, Formal Strategic Plan and Long-Range Plan were between 0.63 and 0.68. Though this exceeded the minimum alpha level of 0.6, in future research the measurement scales should utilise a more consistent set of underlying dimensions which measures the role of automation and its associated functions for that dimension. For all the other scales, alpha values were above 0.7. In general, it can be concluded that the overall reliability results for the scales are acceptable.

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TABLE 5.1  
RELIABILITY ANALYSIS - INTERNAL CONSISTENCY OF SCALES

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INTEGRATED MANUFACTURING USING AMT

	Cronbach's Alpha
CIM	0.69
TQC	0.71
JIT	0.75

FRAMEWORK FOR MANUFACTURING STRATEGY

	Cronbach's Alpha
<u>Adoption</u>	
Formal Strategic Plan	0.64
Long-Range Plan	0.63
<u>Implementation</u>	
Communication of Strategy	0.78
Coordination in Decision Making	0.75
Centralisation in Decision Making	0.77
<u>Evaluation</u>	
Manufacturing Strategy Strength	0.73
Manufacturing Competitive Advantage	0.71

COMPETITIVE PERFORMANCE MEASURES IN MANUFACTURING

	Cronbach's Alpha
Cost	0.73
Quality	0.75
Delivery	0.78
Flexibility	0.77

FACTORS FOR EFFECTIVE MANAGEMENT OF TECHNOLOGY

	Cronbach's Alpha
Recognise Strategic Role of Technology	0.71
Management of Technological Portfolio	0.74
"Hard" Side of Technology - Investment	0.75
"Soft" Side of Technology - Innovation	0.73

BUSINESS PERFORMANCE MEASURES OF A FIRM

	Cronbach's Alpha
Profitability Level	0.76
Generating Increased Sales	0.71
Creating New Opportunities and Facilities	0.74

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### 5.3 CONTENT AND CONSTRUCT VALIDITY

Validity measures the extent to which a scale measures what it is intended to measure. A scale could be reliable, but could measure the "wrong" thing and thus be invalid. Content validity refers to whether the scale has appropriate meaning in relation to the concept being measured. There is no statistical test to check content validity. However, the scales used in this study were

developed from references to the literature, adapted from scales developed by several researchers and pilot tested by managers at various firms for their relevance and clarity. Thus it can be assumed that the content validity is acceptable.

Construct validity refers to the ability of the scale to measure the overall construct it intends to measure, usually as one dimension. In this study, factor analysis was employed to investigate construct validity. If the factor analysis indicates that there is more than one factor for a scale, then two or more different dimensions of the construct are being measured by the scale. This means the scale should be split into two or more parts or nuisance questions should be eliminated from the scale to insure that it measures a single construct.

In this study, factor analysis of principal components with varimax rotation to assess convergence within each scale as well as divergence between scales is used. After achieving a single factor, the eigen values are checked to insure that they exceed 1.0 and the loadings of individual items on the scale are examined (Kim and Mueller, 1978). For this study, any factor loading of an individual item with less than 0.23 is regarded as low, and those items are removed from the scale. A second factor analysis is then conducted, as a confirmatory factor analysis with the remaining items, to check if the new combination loads on one factor.

Tables 5.2, 5.3, 5.4, 5.5 and 5.6 show the results of the factor analysis using maximum likelihood estimates with each scale loaded on a single factor for integrated manufacturing, manufacturing strategy, competitive performance measures, management of technology and business performance measures. As seen from the tables, the eigen values for these scales were greater than 1.0 and the item loadings within each scale are all greater than 0.23. These results indicate that the scales have good construct validity.

TABLE 5.2  
CONSTRUCT VALIDITY - INTEGRATED MANUFACTURING PRACTICES USING AMT

Scale	Categorise Items to Factors											Eigen Values	Variance Explained
	1	2	3	4	5	6	7	8	9	10	11		
CIM	.62	.58	.67	.64	.63	.55	.68	.59	.61	.60	.65	1.84	.69
TQC	.68	.69	.71	.72	.70	.73	.59	.65				2.34	.73
JIT	.59	.61	.58	.71	.68	.65	.66	.70				2.14	.77

TABLE 5.3  
CONSTRUCT VALIDITY - FRAMEWORK FOR MANUFACTURING  
STRATEGY PROCESS USING AMT

	Categorise Items to Factors					Eigen	Variance
Scale	1	2	3	4	5	Value	Explained
<u>Adoption</u>							
Formal Strategic Plan	.72	-.74				1.42	.72
Long-Range Plan	-.56	-.53	-.52	.57	.58	1.18	.65
<u>Implementation</u>							
Commn. of Strategy	.63	-.61	.71	.72		2.36	.67
Coordn. in Decision Making	.71	.74	-.64	.69		1.69	.76
Centrln. in Decision Making	-.59	.55	-.62	.63	.72	2.28	.75
<u>Evaluation</u>							
Manfrng. Strategy Strength	.61	.83	.67	-.45	.54	3.02	.81
Manfrng. Comp. Advantage	.68	.70	.69	.59	.63	2.35	.74

TABLE 5.4  
CONSTRUCT VALIDITY - COMPETITIVE PERFORMANCE MEASURES IN  
MANUFACTURING

Scale	Categorise Items to Factors			Eigen Value	Variance Explained
	1	2	3		
Cost	.42	.56	.58	1.15	.65
Quality	.65	.72	.71	1.42	.73
Delivery	.78	.80	.82	2.36	.83
Flexibility	.69	.63	.65	1.35	.68

TABLE 5.5  
CONSTRUCT VALIDITY - FACTORS FOR EFFECTIVE MANAGEMENT OF  
TECHNOLOGY

Scale	Categorise Items to Factors			Eigen Value	Variance Explained
	1	2	3		
Recognise Strategic Role of Technology	.70	.69	.71	1.98	.71
Management of Technological Portfolio	.72	.70	.77	2.13	.73
"Hard" Side of Technology - Investment	.75	.82	.78	2.36	.82
"Soft" Side of Technology - Innovation	.71	.80	.75	2.24	.75

TABLE 5.6  
CONSTRUCT VALIDITY - BUSINESS PERFORMANCE MEASURES OF A FIRM

Scale	Categorise Items to Factors		Eigen Value	Variance Explained
	1	2		
Profitability Level		.80	.82	2.24
Generating Increased Sales		.73	.77	2.56
Creating New Opportunities And Facilities		.81	.79	2.33

## 5.4 EFFECTS OF AMT IN MANUFACTURING

Multiple regression is widely used to predict the level or magnitude of a dependent variable based on the levels of more than one independent variable (Cohen and Cohen, 1975). It can be used as a descriptive tool to develop a self-weighting estimating equation to predict values for a criterion variable from the values of several predictable variables. The second descriptive application of multiple regression is to control for confounding variables in order to evaluate better the contribution of other variables. In addition to being a descriptive tool, multiple regression is also used as an interface tool to test hypotheses and to estimate population values from sample data.

In this study, multiple regression is used to test the hypotheses formulated in Chapter 3. To test the hypotheses, multiple regression was used to predict each competitive performance measure with the set of integrated manufacturing practices. That is four sets of multiple regression analyses were conducted on cost, quality, delivery, and flexibility with CIM, TQC, and JIT on functional areas in operations, quality, and production control. By surveying across these three functions, the effects of integrated manufacturing examine the input used to produce the goods and the input required to support the production processes of these goods (Snell and Dean, 1992). Previous studies only focused on operations as the major factor, today functions such as quality and production control are also considered important and contribute to the success of integrated manufacturing (Dean and Snell, 1991). As described in Section 3.3.4, the data was obtained from participants at the 35 sites.

The coefficient of multiple correlation for a sample is known as  $R$ , and its square ( $R^2$ ) the coefficient of multiple determination, is calculated. Incremental values of  $R^2$  being greater than 0.25 can be considered statistically significant for this study. The "b" values measures the sampling variability of each regression coefficient and "F" measures the statistical significance of each of the regression coefficients. A "b" value being greater than 0.45 shows good significance. In the first step, the set of integrated manufacturing practices (CIM, TQC, JIT) was entered. Significant incremental values of  $R^2$  in this step could be interpreted as support for the hypotheses (hypotheses 1a -1d) on this basis i.e., each of the singular facets of integrated manufacturing is positively related to each of the competitive

performance measures. In the second step, the three-way interaction of all the practices of integrated manufacturing (CIM x TQC x JIT) with the performance measures were investigated. Significant incremental values of  $R^2$  in this step could be interpreted as support for hypotheses (hypotheses 2a - 2d) on the interactive effects.

Table 5.7 shows the effects of integrated manufacturing on cost in operations, quality, and production control. In Step 1, the set of integrated manufacturing practices (CIM, TQC, JIT) had a positive effect in operations, quality and production control. TQC had a significant effect in quality and production control with "b" values of 0.41 and 0.56 respectively. JIT also shows a more positive effect in quality and production control. These findings provide support to hypothesis 1a that the facets of integrated manufacturing practices using AMT (CIM, TQC, JIT) are positively related to cost.

In Step 2, in the multiple regression analysis for cost, the three-way interaction of CIM, TQC and JIT has good positive effects and significant  $R^2$  values in operations, quality and production control between 0.25 and 0.32. These findings support hypothesis 2a that the interactive effects of manufacturing practices using AMT (CIM, TQC, JIT) are positively related to cost.

Table 5.8 shows the results of the one-way and three-way interactions of CIM, TQC and JIT on operations, quality and production control for the regression analysis for quality. In this case, JIT shows the best positive effects in operations, quality and production control. TQC was more significant in production control with variable "b" having a value of 0.55. All the three-way interactions also produce significant increments in  $R^2$ . These findings provide support for hypotheses 1b and 2b as both the singular and interactive effects of CIM, JIT, and TQC are positively related to quality.

The results in Table 5.9 show the multiple regression analysis for delivery. In the one-way interaction, CIM showed positive effects in operations, quality and production control. The result for TQC was more significant in operations whereas JIT showed consistent values on delivery for operations, quality and production control. All the three-way interactions show significant incremental values of  $R^2$ . Overall the results support the hypotheses 1c and



TABLE 5.7  
RESULTS FOR MULTIPLE REGRESSION ANALYSIS FOR COST<sup>a</sup>

Variables	Operations				Quality				Production Control			
	b	$\Delta R^2$	$R^2$	F	b	$\Delta R^2$	$R^2$	F	b	$\Delta R^2$	$R^2$	F
1-way Interaction		0.19	0.16	1.70		0.21	0.22	3.85		0.12	0.22	5.31
Constant	5.63				8.53				7.11			
CIM	0.25				0.27				0.22			
TQC	0.28**				0.41				0.56			
JIT	0.31				0.39				0.31			
3-way Interaction		0.09	0.25	3.48		0.09	0.29	0.52		0.04	0.32	3.26
Constant	9.61				6.58				5.42*			
CIM x TQC x JIT	0.62				0.61				0.58			
Overall F				4.72				3.30				2.54

TABLE 5.8  
RESULTS FOR MULTIPLE REGRESSION ANALYSIS FOR QUALITY<sup>a</sup>

Variables	Operations				Quality				Production Control			
	b	$\Delta R^2$	$R^2$	F	b	$\Delta R^2$	$R^2$	F	b	$\Delta R^2$	$R^2$	F
1-way Interaction		0.23	0.23	5.58		0.13	0.14	6.01		0.28	0.28	4.73
Constant	1.52				5.27				4.66			
CIM	0.39				0.36				0.28**			
TQC	0.36				0.47				0.55			
JIT	0.52				0.61*				0.58			
3-way Interaction		0.48	0.48	1.92		0.34	0.31	5.42		0.35	0.33	5.66
Constant	1.63				4.99				5.63			
CIM x TQC x JIT	0.48				0.53				0.41			
Overall F				4.32**				6.28				5.33

TABLE 5.9  
RESULTS FOR MULTIPLE REGRESSION ANALYSIS FOR DELIVERY<sup>a</sup>

Variables	Operations				Quality				Production Control			
	b	$\Delta R^2$	$R^2$	F	b	$\Delta R^2$	$R^2$	F	b	$\Delta R^2$	$R^2$	F
1-way Interaction		0.22	0.12	4.89		0.09	0.25	3.85		0.08	0.32	1.91
Constant	2.71				3.88				3.78			
CIM	0.55				0.58				0.61*			
TQC	0.32				0.19**				0.21			
JIT	0.31				0.28				0.23			
3-way Interaction		0.21	0.43	2.34		0.10	0.31	3.67		0.33	0.41	1.83
Constant	5.89				4.87				4.72			
CIM x TQC x JIT	0.67				0.60				0.61			
Overall F				3.92				2.93				3.65

TABLE 5.10  
RESULTS FOR MULTIPLE REGRESSION ANALYSIS FOR FLEXIBILITY<sup>a</sup>

Variables	Operations				Quality				Production Control			
	b	$\Delta R^2$	$R^2$	F	b	$\Delta R^2$	$R^2$	F	b	$\Delta R^2$	$R^2$	F
1-way Interaction		0.10	0.32	5.58		0.08	0.22	3.45		0.12	0.19	2.55
Constant	5.71				3.30				4.72			
CIM	0.62**				0.41				0.39			
TQC	0.29				0.21				0.20			
JIT	0.33				0.37				0.41*			
3-way Interaction		0.41	0.44	1.92		0.38	0.46	2.53		0.39	0.47	3.46
Constant	6.11				5.77				3.87			
CIM x TQC x JIT	0.71				0.61				0.58			
Overall F				2.92**				2.18				1.89*

<sup>a</sup> | Instandardised betas are reported. \*p < 0.05, \*\*p < 0.01.

2c as integrated manufacturing, singularly and in combination, affects the competitive performance measure of delivery.

The results of the multiple regression analysis for flexibility is shown in Table 5.10. CIM has a high correlation for flexibility in operations. TQC provide lower effects but these were consistent. JIT has the best effect for flexibility in production control. The three-way interactions also provide significant incremental values in  $R^2$ . These results again lend support to hypotheses 1d and 2d as integrated manufacturing individually and in combination has a positive relation to flexibility.

All the three way interactions of the facets of integrated manufacturing practices (CIM, TQC, and JIT) showed positive relation on competitive performance measures of cost, quality, delivery, and flexibility. These show a more consistent significant incremental effect when compared with the one way interactions.

## 5.5 MANUFACTURING STRATEGY FRAMEWORK AND PERFORMANCE

Criterion validity refers to whether the scale is related to some external criteria. An integrated manufacturing strategy formulated through a careful adoption, implementation and evaluation procedure should enable the firm to gain a competitive advantage and a high level of manufacturing technology. Thus, if the seven manufacturing strategy scales, relating to adoption, implementation, and evaluation of AMT, are related to the manufacturing competitive performance measures of cost, quality, delivery, and flexibility, criterion validity will be demonstrated. As described in Section 3.3.1, the total measure of each scale is constructed from the items within the scale. The aggregated results obtained for each scale are not presented because the emphasis in this study is to examine the relationship between the set of scales rather than to evaluate the absolute value for each of the scales.

Canonical correlation can be used to assess the strength of association between two different sets of variables. Here, such a correlation was performed between the set of seven variables of the manufacturing strategy process using AMT and the set of four competitive performance measures in manufacturing.

The results of this correlation analysis for the manufacturing strategy process is shown in Table 5.11. The overall canonical correlation of the first canonical variate was 0.87, with a p value of less than 0.03. This canonical variate explained 57 per cent of the variance. The second through fourth canonical variates were not significant at the 0.05 level and were therefore not considered further.

Table 5.11 shows the correlations of each of the seven strategy process scales with the first canonical variate. It is seen that at least one scale in each of the management processes of adoption, implementation, and evaluation of AMT has high correlation, Formal Strategic Plan in adoption, Coordination in Decision Making in implementation, and Manufacturing Strategy Strength in evaluation; the values of correlation for these scales ranging from 0.65 to 0.78. This indicates that the issues represented in these scales are important. From the results of this analysis, it may be concluded that the issues in evaluation of AMT have the highest importance. This is rather surprising because, in spite of the stated importance, only 43 per cent of the participating firms performed a formal evaluation.

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TABLE 5.11  
CRITERION VALIDITY(A)- SCALE RELATED TO EXTERNAL CRITERIA

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	First Canonical Variable
Canonical Correlation	0.87
Significance	0.03
Variance Explained (proportion)	0.57
MANUFACTURING STRATEGY - LOADINGS (correlations)	
<u>Adoption</u>	
Formal Strategic Plan	0.65
Long Range Plan	0.45
<u>Implementation</u>	
Communication of Strategy	0.62
Coordination in Decision Making	0.68
Centralisation in Decision Making	0.64
<u>Evaluation</u>	
Manufacturing Strategy Strength	0.78
Manufacturing Competitive Advantage	0.70
COMPETITIVE PERFORMANCE MEASURES IN MANUFACTURING - LOADINGS (correl.)	
Cost	0.68
Quality	0.78
Delivery	0.81
Flexibility	0.71

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The correlations of the four competitive performance measures in manufacturing are also shown in Table 5.11. All these correlations are high, ranging from 0.81 for delivery to 0.68 for cost at 0.68. This indicates that all these performance measures are also important.

The criterion validity analysis indicates strong relationship between the seven scales of the management processes of adoption, implementation, and evaluation within the manufacturing strategy process using AMT and the selected performance measures. The canonical correlation being high, and statistically significant, supports hypothesis 3 presented in Section 3.3.6, that is, the manufacturing strategy process (adoption, implementation, and evaluation) using AMT (CIM, TQC, JIT) is positively related to the competitive performance measures in manufacturing (cost, quality, delivery and flexibility).

## 5.6 MANAGEMENT OF TECHNOLOGY AND PERFORMANCE

Effective management of technology should enable a firm to attain good profitability levels, generate increased sales, and create new opportunities and facilities. The participating plant managers confirmed the factors represented in the four proposed measurement scales for effective management of technology. If the four management of technology scales are related to the three scales of the performance measures at the business unit level, criterion validity will be demonstrated, i.e., effective management of technology influences business performance.

Table 5.12 shows the results of the canonical correlation analysis between the four scales for the effective management of technology, as one set of variables, and the three criteria of business performance as the second set of variables. The overall canonical correlation of the first canonical variate is 0.84, with a p value less than 0.03. The canonical variate explained 63 per cent of the variance.

The results show the correlations of each of the four management of technology measurement scales with the first canonical variate. It is seen that all the management of technology scales have a high correlation between 0.70 to 0.75. This indicates that the key issues represented in the scales are important in the effective management of technology. As seen the

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TABLE 5.12  
CRITERION VALIDITY(B)- SCALE RELATED TO EXTERNAL CRITERIA

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	First Canonical Variable
Canonical Correlation	0.84
Significance	0.03
Variance Explained (proportion)	0.63
EFFECTIVE MANAGEMENT OF TECHNOLOGY - LOADINGS (correlations)	
Recognise Strategic Role of Technology	0.70
Management of Technological Portfolio	0.71
"Hard" Side of Technology - Investment	0.75
"Soft" Side of Technology - Innovation	0.73
BUSINESS PERFORMANCE MEASURES OF A FIRM - LOADINGS (correlations)	
Profitability Level	0.72
Generating Increased Sales	0.75
Creating New Opportunities and Facilities	0.78

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correlations of the three business performance factors of the firm also show high correlation values between 0.72 to 0.78. This indicates that all the performance variables are also important. The canonical correlation being statistically significant, shows a good fit between effective management of technology and performance measures selected. Thus it can be concluded that if the firm creates a proper strategy to manage technology, it will enable the firm to improve its performance in profitability level, the generation of increased sales and the creation of new opportunities.

An analysis was performed to determine the varying impacts of the firms' responses to new technological developments using the Miles and Snow (1978) typology. Participating plant managers were categorised according to the way their firms approached to new technological developments, opportunistic/proactive or defensive/reactive. Fifteen firms, that is, forty-three per cent were defensive/reactive, they reacted to competitive forces to adopt and use technology in their business. Twenty firms, that is, fifty-seven per cent were opportunistic/proactive in terms of pursuing specific technology related opportunities.

The approaches to taking advantage of new technological developments in manufacturing is operationalised by two variables, Monitor Technological Developments, and Support Technological Developments. The first variable

represents investment of the firm's resources in evaluating new technology and ideas, and systematically examining these ideas to see if they are suitable for use by the firm. The second variable represents the extent of the firm's support in developing and adopting new technologies in manufacturing.

The relationship between monitoring and supporting new technological developments and business performance measures (profitability levels, generating increased sales and creating new opportunities and facilities) was explored using correlation analysis between the two sets of variables. Table 5.13 presents the results of this analysis.

TABLE 5.13 CORRELATION ANALYSIS BETWEEN NEW TECHNOLOGICAL DEVELOPMENT AND BUSINESS PERFORMANCE OF A FIRM			
New Technological Developments	Profitability Levels	Generating Increased Sales	Creating New Opportunities and Facilities
OPPORTUNISTIC/PROACTIVE (n=20)			
Monitor Technological Developments	-.456 p=0.311	.561 p=0.015	.641 p=0.003
Support Technological Developments	-.091 p=0.67	.491 p=0.03	.543 p=0.02
DEFENSIVE/REACTIVE (n=15)			
Monitor Technological Developments	.667 p=0.003	.512 p=0.001	.502 p=0.03
Support Technological Developments	.432 p=0.08	.201 p=0.11	.459 p=0.009

In the case of firms with an opportunistic/proactive response, there exists a positive correlations between the approaches to new technological developments and two performance measures, generating increased sales and creating new opportunities and facilities. In correlation where the coefficient value is greater than 0.5, the result can be judged statistically significant. A negative correlation value will suggest that new technological developments do not support the business performance of a firm. There is a strong positive correlation (coefficient 0.641) between monitoring new technological developments and creating new opportunities and facilities. A positive correlation (coefficient 0.543) exists between supporting new technological development and creating new opportunities and facilities.

Negative correlations exist between the two variables of new technological developments and profitability level. These results show that the firms in this group are risk takers, and invest more in technology for long-term returns. They maintain a competitive advantage through technological leadership in new products and processes.

The results of the correlation analysis for the defensive/reactive response are presented in the second part of Table 5.13. All correlations between approaches to new technological developments and the three performance measures are positive. However, the correlation between supporting new technological developments and generating increased sales is statistically not significant with a coefficient value of 0.201. This means that these firms do not actively support new technological developments for adoption in manufacturing to generate increased sales. The analysis highlights the fact that these firms are more conservative in their investment in new technologies. These firms are risk avoiders and, in order to maintain their market shares, they invest in new technologies directly related to their existing products. Their investment is more focused, and they tend to gain from new technological developments, both in the short and long term.



## **CHAPTER 6**

### **CONCLUSIONS**

#### **6.1 SUMMARY**

In the 1980s, the declining competitiveness of European manufacturers has received considerable attention. Numerous articles have documented their weakening competitive position in global markets, the decline of their manufacturing base, and the continued closure of manufacturing plants in U.S. and Europe. Attention has focused on manufacturing strategy and technological innovation in manufacturing as possible solutions to these growing problems. Adoption and implementation of new manufacturing technologies, known collectively as advanced manufacturing technology (AMT), offered the promise of successfully competing in global markets. Specifically, these technologies offered advantages in those areas that European manufacturers needed to address: cost, quality, flexibility, and delivery. However there are two major concerns regarding these issues: (1) European manufacturers have been slow to adopt AMT, and (2) those firms that have decided to adopt these new technologies, have to date had limited success in implementing them.

If widespread use of advanced manufacturing technologies was critical for manufacturers to regain their competitive position, then there was also a need for a clear understanding of the management processes required to achieve success. Management in the 1980s had limited experience with AMT and few guidelines then existed to assist managers in their transition to these technologies. This study has pursued an in-depth, integrative research approach to address these issues by focusing on the experiences of firms pursuing a strategy of automation.

Using a multiple case study approach, the first exploratory part of this study investigates the reasons why European firms chose to adopt advanced manufacturing technologies and the decision-making processes involved in justifying these systems. In addition, this study has identified obstacles to the justification process to provide insight into how firms have either ignored or overcome some of these obstacles. The decision to adopt these new

technologies is only the first step in becoming or remaining competitive. Once these technologies are adopted, they need to be successfully implemented to achieve the proposed benefits. This research provides insight into how firms managed their AMT implementations and identified the obstacles they encountered during the process. In addition, factors that contributed to or impeded successful implementation were identified. The difficulties of performing post-implementation evaluations by these firms were also examined. The results drawn from this study corroborate earlier findings that comprehensive retrospective evaluations of AMT projects are rarely performed. Finally, some important, wider issues in management of technology are explored. The issues identified as important by the participating firms are the strategic role of technology, time-based competition, and outsourcing of technology, to be considered in integrating technology with the business strategy.

Using a detailed questionnaire survey, the second quantitative part of this study explores the links between the competitive performance measures in manufacturing and the management processes of adoption, implementation, and evaluation of AMT in integrated manufacturing (CIM, TQC, JIT) within the proposed manufacturing strategy framework. As management of technology issues were considered important by participants, these issues were operationalised to examine their impacts on the performance measures at the business unit level.

## 6.2 CONCLUSIONS: QUALITATIVE MULTIPLE CASE ANALYSES

The following sections present the conclusions from the results of multiple case analyses.

### 6.2.1 Adoption

The study results corroborate reports in the literature about why firms adopt advanced manufacturing technology. The reasons why firms pursue a strategy of automation are as varied as the number of firms. However, the five most frequently mentioned reasons for adoption of AMT were:

1. Maintain or improve competitive advantage.
2. Improve quality.
3. Stay on the leading edge of manufacturing technology.
4. Reduce manufacturing costs.
5. Reduce labour.

While management has been criticised for ignoring the strategic implications of emerging technologies, the individuals participating in this study perceive that there are strategic advantages to be gained from adopting AMT.

Some eighty per cent of the firms said they prepared a formal strategic plan. In addition, manufacturing usually had an input into the plan and a separate strategic manufacturing plan was often developed. On the other hand, the companies which had not developed an overall strategic plan, specifically outlining their philosophy for adoption and implementation of AMT, frequently encountered difficulties. In particular, islands of automation began to spring up across some firms. In other cases, the transition from one management team to the next brought about major reversals in the approach to adopting and implementing emerging technologies.

Perhaps the most interesting and surprising findings of this study relate to the justification process, often described as the single greatest barrier to the factory of the future. In general, justification of AMT was found to follow the same process as justification for any capital investment. However, the process varied considerably among the firms as the degree of uncertainty increased and as the level at which AMT proposals were initiated within the firms changed.

The most common investment analysis methods reported by these firms were payback and return on investment. Both of these techniques are generally criticised as having serious flaws in evaluating investments, in particular for long-range projects of this nature. For the participating firms, the acceptable payback period ranged from one year to a maximum of three years. Application of this short-term outlook to a long-term project encourages a piecemeal approach to automation and many appropriate AMT projects may be rejected as a result. In addition, these techniques are based on financial rather than strategic considerations and fail to capture the numerous strategic benefits typically associated with the implementation of AMT.

Considerable frustration was experienced by the study participants as they tried to identify and quantify benefits, both tangible and intangible. While a few attempts were made to quantify the intangible benefits with estimates or guesses, usually they were simply omitted from the financial justification, thereby assigning them a zero value. Proponents of automation projects

attempted to account for these factors by listing them on the appropriation request form.

As shown in this research, if the expected return or payback period did not meet the required criteria established by the firms, then the justification became much more involved. Over 50 per cent of the participants mentioned that if the project was not justified on a financial basis then you have to "get creative." Specifically, it was common to exaggerate the benefits or modify the numbers in order to meet the established hurdle rates. In addition, financial justification was often supplemented with a rationale based on the strategic implications of the proposed AMT project.

The most surprising result of this study was that approximately 25 per cent of the proposed projects were approved without any financial justification. This finding corroborates Dean's (1987) work. Typically, these were very large, integrated AMT projects, requiring multi million dollar investments. In general, as the degree of uncertainty increased, (time horizons extend into the future; level of automation and degree of integration of AMT increases; risks are not easily identified and quantified) the methods of justification come to rely on less formal, qualitative approaches. In certain cases, if projects were initiated by a champion from top management, the routine justification process was often bypassed and less formal, qualitative justification approaches were used or no justification was prepared.

These findings suggest that management needs to re-evaluate the entire justification process. While traditional financial investment analysis techniques remain effective for short-range, equipment replacement decisions, the wisdom of employing these techniques for strategic investments may be questioned. Management may well determine that preparation of financial justification is not necessary, assuming the project supports the overall strategic plan of the organisation. On the other hand, broadening traditional financial analyses to include subjective estimates of strategic considerations, may be another approach. Kaplan (1986) urges management not to act on "faith alone" and "not to take the easy way out and discard the necessary discipline of financial analysis". None of the firms in this study used any of the alternative justification approaches described in Chapter 2. Following this line of thought, justification of AMT projects should be based on a combination of techniques (economic, analytic, and strategic),

in order to give management a better assessment of the investment opportunity.

It is proposed that justification of AMT should consider the following: (1) use of sufficiently long-range planning (eg. five to seven years); (2) use of discounted cash flow techniques (eg. net present value) in addition to payback and ROI; (3) use of both quantitative and qualitative measures; (4) inclusion of a subjective ranking/weighting scheme to account for intangible, qualitative measures; and (5) assessment of risks and identification of strategies for managing risks. Based on information derived from the participating firms, it seems that major modifications to the justification process will be required and fairly extensive education will be necessary for managers at all levels.

The policy changes necessary to implement these suggestions may be thwarted by what the study participants perceived to be the number one obstacle to justification: problems with top and middle management. When the interview teams were questioned about the barriers to justification of their AMT projects, they responded with three main concerns:

1. Management problems.
2. Cost and risk.
3. Justification technique.

While the obstacles mentioned were expected, the results were somewhat surprising. Based on the literature, the expectation was that the financial analysis techniques would present the major problems in justifying AMT.

The two key concerns about management were: (1) changes in management led to shifts in the philosophy of adopting AMT and (2) both top and middle management were resistant to change. Problems stemming from changes in management may be alleviated if a firm develops an overall strategic plan, supported by manufacturing and technology strategic plans. With an overall plan guiding the organisation of AMT, changes in management should be transparent and have little effect.

The second issue, uniformed and resistant management, poses a significant problem. The implication is that top management may throw obstacles in the path of the proponents of automation and either reject proposals or significantly delay justification of proposals for AMT. Clearly, conceptual

education about advanced manufacturing technology for upper and middle level management is necessary. Ideally, this education would take place prior to or be concurrent with the adoption and justification phase.

The costs and risks associated with adopting and implementing AMT were perceived to be major obstacles to justification. Investment in these complex systems is very substantial, starts from a significant base, and is not bounded. As the price tag soars, the difficulty of justifying these projects increases. In addition, excessive financial and organisational risks are associated with adoption and implementation of AMT.

### 6.2.2 Implementation

This study reported on the process of implementing AMT and specifically focused on how participating firms managed this complex process. Also, the participants' assessments of the factors critical to a successful implementation were reported and compared with earlier studies.

Perhaps the most important finding from investigating the implementation process was that the results from this study confirm earlier research on critical success factors. The four most frequently mentioned factors considered important to a successful implementation were:

1. Project management.
2. Participation.
3. Understanding of the manufacturing process.
4. Incremental implementation strategy.

The most frequently reported factor, accounting for success or failure in implementation of AMT, was project management. This was expected since the participating firms were surprisingly consistent in their approaches to managing the implementation process. All the firms used commonly accepted project management techniques to assist in their implementations, such as: (1) selection of a project leader, (2) selection of a project team, and (3) development of an implementation plan. In addition, most of the research sites monitored the schedule and budget of their projects, using a variety of techniques such as: PERT, CPM, Gantt charts and accounting cost reports.

While formal project leaders were typically assigned or appointed to head the implementation process, this was rarely a full-time position. As a result frequent conflicts developed between project-related tasks and ongoing job

responsibilities. Creation of formal project implementation teams, with representation from every affected department and functional area, was reported by 94 per cent of the firms. A multi disciplinary project team was frequently proposed as a way to overcome resistance to change and to encourage early involvement and anticipation from all levels in a company - the second critical success factor. In addition, both the size and stability of the project team appeared to impact the implementation. In particular, a stable core of participants in the implementation team plays a role in maintaining a consistent approach to the implementation. Changes in implementation or management teams may have a negative impact on the outcome of the AMT project.

One theme emerged consistently throughout the interviews: project teams typically underestimated the time required to implement AMT. Management should take this into consideration, since the slippage in schedules may well translate into substantial cost overruns for the firm.

It was not surprising that participation was considered to be of critical importance in the overall success of an AMT implementation. This result corroborates earlier studies, which have consistently correlated user participation and management involvement (the two components of participation) with implementation success. Participation from all levels within the organisation was stressed by the participants as a method for overcoming resistance to change, a major obstacle to implementation identified in the study.

Understanding the manufacturing process was identified as another key factor which contributes to the success or failure of an AMT implementation. The study results emphasised the importance of performing a detailed analysis of the production process before proceeding with actual implementation of automated technologies. Typically referred to as an "as is" study, the purpose is to identify existing weaknesses in the firm's production process and correct them before automating. In some cases, it may be determined that automation is inappropriate. Less than one-fourth of the firms performed an in-depth "as is" analysis of their manufacturing processes. It is somewhat ironic that so few firms performed this analysis, yet many perceived it as essential to the implementation of AMT. Failure to "nail down the manufacturing process" during the early stages may have a ripple

effect throughout the implementation and may very well lead to major difficulties or even failure.

Incremental implementation strategy was identified as another critical success factor in an AMT implementation. Trying too much too fast was a common mistake and led to frustration and sometimes failure. Especially since most of the participants had limited or no experience with these new technologies, a phased implementation was considered to be appropriate. In addition, an incremental, phased implementation implies that there is some overall technology strategy guiding the organisation. This factor supports the earlier discussion about the importance of manufacturing and technology strategies in relation to the adoption and implementation of AMT.

A number of other factors were mentioned by respondents as being critical to a successful implementation of AMT, such as: properly functioning equipment, supplier-user relationships, training, integration, justification and communication. Each of these factors confirms the results of earlier research on critical success factors.

When the participants were questioned about the barriers to implementation of their AMT projects, they responded with three main concerns:

1. Resistance to change.
2. Technical problems.
3. Lack of effective project team.

Two of the three major obstacles identified by the participating firms were managerial. The response to this question is notable because it confirms the idea proposed in the literature that managerial problems rather than technical problems often present the greatest challenges to the firm implementing AMT. It is not surprising that the critical success factors identified by the participants address each of these major obstacles.

This study confirms that firms implementing advanced manufacturing technologies rely heavily on external resources. Outside consultants were used extensively during the implementation process. The degree and extent of involvement by consultants varied across the firms, ranging from relatively minor technical assistance to full responsibility for project implementation. In addition, the participants emphasised the importance of a strong, positive relationship with the vendors and suppliers of AMT to the success of the



implementation. Although a number of problems were encountered with both consultants and suppliers, the relationships were described as extremely positive.

Even though the results of this study indicate that training and education are important components of the implementation of AMT, the participants did not rank training and education as one of the most critical success factors. Since automation touches almost everyone and extensive change is usually required, one would expect education and training to be a major effort. While firms were not ignoring this issue, very few had devised extensive strategies to deal with it. A number of experimental, innovative training programmes were being introduced by some of the firms, however, in general there was a strong reliance on vendors to supply training for operators. In addition, outside consultants were retained in a number of cases to provide conceptual education for middle and upper levels of management.

Management needs to address the issues of developing a human resource strategy, which incorporates comprehensive training and education programmes appropriate for all levels in the firm. As noted in the discussion about justification, one way to overcome problems with management and resistance to change, is to provide education about the capabilities of AMT and potential benefits. Similarly, the process of implementation would progress more smoothly if supported by a comprehensive training and education programme. Relying solely on vendors to provide training may also result in problems, for as the degree of integration increases, the ability to provide adequate training by single vendors will decrease. Additional training will be necessary to supplement that provided by vendors for their particular systems, as islands of automation are linked together.

In order to explore the impact on a firm implementing AMT, participants in this study were asked to describe the ways in which automation caused changes in their organisations. The five most frequently mentioned changes were:

1. Nature of job and job responsibilities.
2. Employee morale and job satisfaction.
3. Formal procedures.
4. Organisational structure.
5. Organisational culture.

Examples were offered to illustrate the changes reported by the participating firms. As expected, dramatic changes are taking place and firms are responding to these changes. Additional research, particularly by those specialising in organisational behaviour, is required to explore each of these topics in depth.

Minimising potential risks and overcoming the obstacles to implementation may be accomplished by paying particular attention to the factors considered critical to a successful implementation. However, as indicated in the following section, the ability to identify a successful implementation is hampered by limited retrospective evaluations being performed by firms implementing AMT.

### 6.2.3 Evaluation

Given the reports in the literature about the limited success of firms implementing automated technologies, one might expect the participants in this study to have the same experience. However, when questioned about their satisfaction with their factory automation systems, it was found that the participants were "generally satisfied" to "very satisfied" with their AMT systems. The general perception was that progress had been made in the implementation of AMT, but much work remained to be done. Several possible explanations were discussed in Chapter 4 to explain this somewhat surprising result, such as positive bias on the part of the respondent or averaging all systems together. However, the "middle of the road" type responses may also reflect the limited formal evaluations performed by these firms. In effect, without measuring and qualifying the benefits achieved, it cannot be stated with any degree of certainty whether the implementation was a success or a failure.

Following-up on the level of satisfaction with their advanced manufacturing systems, the participants were asked to enumerate the benefits achieved from implementing their AMT projects. The list of benefits is long and varied. However, the most frequently mentioned benefit was improved quality, reported by all of the respondents. The results from this study confirmed the notion that synergistic benefits accrue to users of AMT, particularly as various systems are integrated. Approximately two-thirds of the respondents believed that they gained synergistic benefits as a result of implementing their automated systems.

While these results are interesting and supportive of the literature, the benefits reported are generally subjective and reflect the perceptions of the participants. Once again, the ability to confirm or deny the proposed benefits associated with AMT is limited, given the fact that implementors had not performed comprehensive evaluations.

The study results corroborate the findings of earlier work: comprehensive retrospective evaluations of AMT projects are rarely performed. Over three-quarters of the firms had not performed a formal evaluation of their advanced manufacturing systems. Given the fact that many of these projects cost millions of dollars and require substantial human capital, the overall lack of concern about a follow-up is both surprising and unsettling.

Questioned about why they were not performing post-implementation evaluations, the participants all responded with the same general observations. First, the "before" data either did not exist or if it did was not recorded before the implementation process began. As a result, the "before" data could not be compared with the "after" data. Second, the ever-changing nature of the business and the impacts of the AMT implementation on organisation, made it infeasible to perform a post-implementation evaluation. Third, formal evaluations were usually not required by top management. In addition, it might be quite possible that the implementation teams were concerned about unearthing less than desirable results, which could significantly impact their careers.

Management needs to reconsider the entire evaluation process. The results of this study indicate that comprehensive retrospective evaluations are not yet a priority for corporate management. As discussed in Chapter 2, there are a number of compelling reasons to perform a review of a major project like the implementation of AMT. Once again, top management must strike a balance between risk and reward in order to encourage managers to undertake evaluations of their AMT projects. In addition, mechanisms need to be put in place in order to collect and analyse data. Not only must specific performance measures be identified, but a method must be devised to measure and analyse them.

#### 6.2.4 Management of Technology

In the past, management of technology referred to issues related to company research and development and how to link them with marketing and manufacturing. Today it extends beyond research and development to include the integration of design, manufacturing and marketing, the balance between product and process innovation and the acquisition and integration of externally developed technology.

Participants in this study were asked to identify the most important issues in technology management for their firms. They identified three key issues related to integrating technology with business strategy, strategic nature of technology, time-based competition, and outsourcing of technology.

The technology-integrated business strategy addresses both the market and technology forces (market pull and technology push) which impact on the competitive position and long-term profit potential of a business. It considers the factors that are important in the effective utilisation of technology in all aspects of the business.

The appearance of new products and services at a relentless pace clearly demonstrates how critical to an industry's competitiveness is the mastery of technology, whether it exists within or outside the firm/industry. The strategic management of technology takes into consideration short and long-term corporate objectives and translates them into action plans. The planning process consists of a combination of technical and market factors, which takes into account the optimum distribution and use of resources, the right mix of skills and talents and the development of a portfolio and set of effectiveness criteria. The understanding of the needs and constraints of technology and manufacturing issues in concert with the business strategy of the firm will provide a strong competitive edge for existing and future business practices.

#### 6.3 CONCLUSIONS: QUANTITATIVE ANALYSES

The following sections present the conclusions drawn from the results of quantitative analyses.

### 6.3.1 Effects of AMT in Manufacturing

Multiple regression is used to analyse the effect of the three practices of integrated manufacturing (CIM, TQC, JIT) on the competitive performance measure in manufacturing. The one-way interactions of the integrated manufacturing practices show a positive effect on the performance measures. This supports the hypotheses on the basis that each of the singular facets of integrated manufacturing is positively related to each of the competitive performance measures. The three-way interactions show a more consistent significant incremental effect when compared to the one-way interactions across the four performance measures. Thus the three facets of integrated manufacturing practices (CIM, TQC, JIT) jointly influence all the four competitive performance measures of cost, quality, delivery, and flexibility. This means that integrated manufacturing can be used to achieve the desired benefits in cost, quality, delivery, and flexibility.

### 6.3.2 Manufacturing Strategy Framework and Performance

The management processes of adoption, implementation, and evaluation of AMT within the proposed manufacturing strategy framework were correlated with manufacturing performance measures. Seven scales were proposed for the overall framework and they were found to be reliable. The scales showed good reliability with Cronbach's alpha exceeding 0.6 and construct validity with eigen values and loadings exceeding the minimum established requirements of 1.0 and 0.23 respectively. Criterion validity was also very good with 0.87 for the first canonical variate, indicating good correlations between these scales and the competitive performance measures in manufacturing. The canonical correlation being high, and statistically significant, supports hypothesis 3 presented in Section 3.3.6, that is, the manufacturing strategy process (adoption, implementation, and evaluation) using AMT (CIM, TQC, JIT) is positively related to the competitive performance measures in manufacturing (cost, quality, delivery, and flexibility).

### 6.3.3 Management of Technology and Performance

The scales used to describe the factors for effective management of technology and the performance factors at the business unit level have good internal consistency with Cronbach alphas exceeding 0.70. The scales also

showed good construct validity with eigen values and loadings exceeding the minimum established requirements of 1.0 and 0.23 respectively. Criterion validity was also good with a canonical correlation coefficient of 0.84 with the first variate. This means that an effective management of technology should enable the firm to attain good performance at the business unit level in terms of profitability, generating increased sales, and creating new opportunities and facilities.

The approach of firms to new technological developments was operationalised by two complementary measures, monitoring and supporting these developments, to see if their approach had any bearing on business performance. Firms monitor, adopt, and integrate new ideas into products and processes differently. The opportunistic/proactive firms generally benefit from both monitoring and supporting new technological developments in generating increased sales and in creating new opportunities and facilities. Correlation values of 0.641 and 0.543 were obtained respectively for the above. A positive correlation with coefficient value being greater than 0.5 indicates that this value is statistically significant. The results also indicate that the firms in this group invest more in technology for long-term results although sacrificing profitability in the short-term. The defensive/reactive firms generally have consistent performance in all three measures as seen from the correlations between the two sets of variables. The analysis highlights the fact that this group of firms are more conservative in their investment in new technologies. These firms are risk avoiders. They tend to invest in new technologies directly related to their existing products. These firms tend to gain from new technological developments, both in the short and long term.

#### 6.4 IMPLICATIONS FOR FUTURE RESEARCH

The purpose of this study was to perform an in-depth examination of the process of adoption, implementation, and evaluation of AMT. A field study, using multiple case studies, captured the experiences of the users directly involved with these processes. While this research was appropriate for an exploratory study, there are limitations inherent in the approach adopted. Given the relatively small sample size, ability to generalise the results to a broader population of firms may be limited. Therefore, conclusions drawn from the field study should be considered as propositions, and would require verification in different settings. More multiple case studies across a broad

range of firms could be employed to verify and extend the findings of this study. In addition, longitudinal studies, tracing AMT projects from initiation to final post-implementation evaluation could shed further light on the processes involved. It would also be worthwhile to investigate firms that have failed in their attempts to implement these technologies, in order to gain another perspective.

Although the second part of this study, through a detailed questionnaire survey, presents some quantitative analyses of factors relevant to the processes of adoption, implementation, and evaluation of AMT, and its management, the results cannot be generalised without further verification in wider settings incorporating a broader range of firms, and more business performance measures. It is also necessary to consider the time-dynamic nature of the factors.

This section identifies a number of opportunities for possible extensions of the present study. The following propositions are drawn from the results discussed in Chapters 4 and 5.

1. The key factors critical to the success or failure of an AMT implementation are: project management, participation, understanding the manufacturing process, and incremental implementation strategy.

The results of this study imply that there is little difference in the project management techniques required to implement AMT from any other major, long-range implementation project. Therefore, a predictive model could be devised (eg. discriminant function), using a set of variables identified from existing theories and models of implementation. The model could then be tested across a variety of implementations, including AMT projects.

2. There appears to be a relationship between the method of justification and the degree of uncertainty. As the degree of uncertainty increases, the method of justification relies on less formal, qualitative approaches. As the degree of uncertainty decreases, the method of justification relies on more formal, traditional quantitative approaches.
3. There appears to be a relationship between the method of justification and the level of project initiation within the organisation. Projects initiated by a champion from top management, often bypassed the routine justification process and were frequently justified using a less formal, qualitative approach. On the other hand, projects initiated from the lower levels of the organisation, generally followed the normal steps in the capital justification process and were justified using a more formal, quantitative approach.

These two propositions focus on the justification process. It would be interesting to explore these relationships across a broader sample of firms implementing AMT. Comparison of justification techniques and processes for AMT projects versus other large scale strategic projects would provide additional insight into the process.

4. There appears to be a relationship between the degree of automation and a formal strategic plan. Firms with an overall strategic business plan, supported by manufacturing and technology strategies, tend to implement more extensive and fully integrated automated systems than firms which do not have an overall strategic business plan, supported by manufacturing and technology strategies.

This proposition underscores the importance of manufacturing and technology strategies to a comprehensive and integrated approach to adoption and implementation of AMT. This requires further investigation in other settings in order to understand the impact of pursuing such a major undertaking without benefit of a strategic plan. The study results indicate that firms which proceed without a strategic plan guiding the overall process may end up with islands of automation scattered throughout the organisation, with little or no integration. Since it is proposed that synergistic benefits accrue as integration increases, an overall business strategy incorporating manufacturing and technology strategies appears to be vital to achieving anticipated benefits.

5. There may be a relationship between the degree of automation and the size of firm, type of industry, and age of the industry. The results from this study indicated that large firms in younger industries, specifically in the aerospace and computer/telecommunications industries, tended to adopt and implement much more extensive and highly integrated systems.

This proposition may be relevant only to leading-edge firms or early adopters of automated manufacturing technologies. As firms in a variety of industries gain experience with these new technologies, the distinction between age, type and size of organisation adopting and implementing AMT will not be transparent. It is hoped that the work reported here will help document how these leading-edge firms were able to justify and implement AMT and allow these processes to eventually become universal. Until such a time, however, further research on the characteristics of firms and industries adopting emerging technologies is suggested.

6. Integrated manufacturing practices(CIM, TQC, JIT) can be used to achieve the desired benefits in cost, quality, delivery, and flexibility. The management processes of adoption, implementation, and evaluation of AMT within the proposed manufacturing strategy influence the competitive performance measures in manufacturing. There appears to be a relationship between



effective management of technology and performance at the business unit level.

Further theoretical and measurement work is required to develop and test these generalisable propositions across a wider range of firms over time. Though managers seem to be taking action to align manufacturing performance measures with integrated manufacturing, the actual measured performance improvements are not known. It has been argued that trade-offs among the competitive performance measures of cost, quality, delivery, and flexibility are no longer necessary (Collins and Schmenner, 1993). This argument should be field-tested empirically.

New scales could be developed for the management processes of adoption, implementation, and evaluation of AMT within the proposed manufacturing strategy framework, depending on the specific needs of a particular industry. New scales of performance measures reflecting product complexity, early supplier involvement and worker empowerment could also be included. Future research should also examine the impact of management of technology on the business performance measures across a wider range of firms identifying a larger number of business performance measures over time.

7. The strategic role of technology is to continuously acquire, manage and exploit technology to increase and improve business operations. Thus the technology fit to the corporate strategy must be evaluated in its entirety.

This proposition is useful to firms who make use of the technology to drive their business strategy. As business strategies change with environment, time, and other macro and micro-factors, their impact on technology resources must be assessed. The following questions require an answer:

- (a) Does the firm exploit current technologies for maximum competitive advantage?
- (b) Does the firm monitor and respond to threats from new technologies?
- (c) Has the firm exploited the full potential of its current technologies to enter new areas?
- (d) Does the firm appreciate the risk/reward outlook of its technological diversification?

Further research is needed to examine the development and maintenance of the firm's technology. The issues to be considered in this are: role of top

management, regular technology audit, technology forecasting, and clear planning for investments. Research on advanced manufacturing technology is still in the exploratory stages. Field-based and empirical research studies are needed to address the issues raised throughout this study.

## **CHAPTER 7**

### **A BEST PRACTICE MODEL FOR AMT MANAGEMENT**

#### **7.1 MANAGERIAL IMPLICATIONS**

From a practical point of view, the way in which manufacturing is planned and manufacturing strategies are implemented must be changed. The traditional technocratic handling of technology implementation must be replaced or supplemented by a broader approach, and one way to ensure this is to strive for an integrative approach. For this, some important issues from the conclusions of this study is summarised.

##### **7.1.1 Adoption and Justification of AMT**

The basic management implication of the conclusions of this study is that the adoption of AMT should be based on a "technology-push strategy"; that a firm's business strategy should drive its manufacturing and technology strategy; and that it should be also recognised that unless a general agreement and support exists at all levels within the firm, specific investments in new technology may run contrary to the firm's overall strategic plan, resulting in islands of automation scattered across the firm with little or no integration. The justification process relating to AMT investment proposals also needed to be made more precise and comprehensive. Therefore, a best practice approach for management with regard to the twin processes of adoption and justification of AMT, may be summarised as follows:

1. Adoption of AMT should be based on a "technology-push strategy". Investments should be evaluated and investment decisions made on the basis of sound business needs, as defined in the firm's formal strategic plan. The business strategy should drive the manufacturing and technology strategies.
2. Evaluate current practices in terms of goals, needs, and priorities of the firm. Identify those activities that inhibit the firm's ability to reach goals. List improvements expected from automation. Identifying these problems and needs is essential to the successful adaptation of the new technologies.
3. Make sure the firm understands the new technologies and what they involve. Accurate cost and operating information through suppliers and competitors should be assembled.

4. Conceptual education and training related to AMT should be provided to top and middle level management, prior to or concurrent with the adoption and justification phase.
5. Management needs to re-evaluate the entire justification process. It is suggested that justification of AMT projects be based on a combination of techniques (economic, analytical and strategic), in order to give management a more reliable and better assessment of the investment opportunity.
6. A balance must be struck between risk and reward, in order to encourage managers to champion investments in AMT. The reward and incentive systems need to be evaluated and modified to encourage this behaviour and to reduce "career risk".

### 7.1.2 Implementation of AMT

The approval, purchase and installation of automated manufacturing technologies is for many firms a lengthy and difficult process, and the successful introduction of such systems is not always readily attained. Implementation is a complex task, often requiring a variety of major and minor changes virtually extending throughout the firm. In undertaking the implementation process, management needs to pay special attention to front-end planning and analysis while following an overall technology strategy. The phasing of the implementation should be accomplished by defining manageable stages and the process requires the participation of the firm's employees at all levels. The following primary considerations thus need to be given attention by management:

7. Effective project management methods are critical to the success of the project and therefore it is essential to form a project team with a project leader and to establish appropriate implementation planning and tracking systems.
8. The right supplier or vendor of AMT should be selected. Make sure the vendor knows manufacturing operations as well as information systems. Issues such as types of support, reputation, track record, commitment to customers, ability to tie to the firm's existing system into their proposed equipment, and types of communication technologies they use need to be addressed.
9. Strong efforts should be made to understand, document and simplify the manufacturing process before automation is introduced.
10. A human resources strategy should be developed, which should include a comprehensive training and education programme, and it should be designed to encourage employee participation at all levels within the firm during the implementation process. It is important people from the shop floor, purchasing, materials, finance, engineering, and marketing all be involved in the project as a team.
11. An incremental, phased approach to implementation, which supports the overall technology strategy, should be followed.

### 7.1.3 Evaluation of AMT

Systematic evaluation of AMT projects should be a feature of any viable attempt to introduce new technological systems and processes into a firm's overall productive operations. By formalising its evaluation methods and procedure, the management can gain a much more accurate assessment of actual benefits achieved and costs incurred. The feedback from evaluations reviews may often suggest some possible corrective/alternative courses of action, as well as also shedding light on particular difficulties encountered during project implementation. Management should take account of the following requirements:

12. During the justification of AMT process, there should be clear definition of the objectives and of the target performance measures to be achieved. In addition, methods to define and analyse performance measures should be collected.
13. Periodic, formal implementation reviews should be undertaken throughout the implementation process. Original objectives and target performance measures should be evaluated, and corrective action or alternative courses of action should be taken when necessary.
14. Formal, comprehensive post-implementation evaluations should be realised. The actual cost and performance measures upon which the AMT system's justification was originally based should be systematically reviewed.

### 7.1.4 Strategic Management of Technology

Within the firm the strategic management of technology is the responsibility of top management, and it is the prime duty of such managers continuously to identify and assess critical issues regarding technology. The essential ingredient of managerial success is to be found in understanding and development of a technology strategy integrated with the firm's business strategy. The following guidelines for management are suggested:

15. Technology-based resources should be utilised in order to achieve an overall competitive business edge through the creation of a technology, business and optimum human resources usage.
16. Product development ahead of the competition should be undertaken in areas of need as identified by strategic business planning, even though existing techniques may fall short of fulfilling that need.
17. A range of technologies, internally mastered and/or externally developed, should be constituted to respond to business threats and opportunities.
18. Assessments and responses to the perceived future needs and threats should be included in the firm's business plan.

19. Environmental, safety and product quality issues should be dealt with before they become a threat.

Managers of industrial companies are realising more and more that improvements in manufacturing help them compete effectively. In addition, they are also realising that in order to make these improvements in manufacturing they must develop and use manufacturing technology.

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## APPENDIX A

### INTERVIEW PROTOCOL

#### PURPOSE

I am conducting research on the implementation of Advanced Manufacturing Technology (AMT) in manufacturing firms. This research is part of my doctoral thesis. The objective of this study is to explore the processes of adoption and justification, implementation, and evaluation of factory automation systems and finally how these technologies are managed. By interviewing leaders in the field, I hope to provide a clearer understanding of the important issues and challenges facing European manufacturers.

#### FORMAT

I want to thank you for inviting me to your office so that I can include your views and experiences in my research study. To gather these, I will be interviewing you in an informal way... that is, I will ask you a set of questions in a general order. I am interviewing you in this way in order to compare your views with those of others I will interview for this study.

Before we begin, let me explain how we will proceed. First, I will ask you to describe your organisation and automated systems which are planned or implemented at your firm. Second, I will ask you several questions about the adoption and justification of your systems. Next, we will discuss the implementation process. Then I will ask you about the evaluation of your factory automation systems. Finally, we will discuss the technological implications and its management in your business.

To conclude, I will leave you with a brief questionnaire which supplements the information provided by you during the interview. The purpose of this is to gain background information about your experiences, and information about your company.

#### ANONYMITY

Your individual responses will be treated confidentially and your anonymity will be protected. The name of your company will not appear in any publication which is based on the information collected during this interview or through the questionnaire.

#### THANK YOU.

## APPENDIX A

### INTERVIEW PROTOCOL AT RESEARCH FIRMS

#### ADOPTION

**Why was the decision made to implement AMT?**

*Probes:*

*Strategic Factors (customer demand, competitive edge, modernise, new products)*

*Operational Factors (reduce WIP, Lead time, Labour, quality, safety)*

*Competitive Necessity (necessity within industry?, Why?, Within 5 years?)*

*Firm has a manufacturing strategic plan?*

**Describe decision-making process used for your factory automation systems.**

*Probes:*

*What year did you begin planning for factory automation?*

*How long did the decision process take?*

*Who was involved in the decision-making process? (titles and levels)*

#### JUSTIFICATION

**How were you automated systems justified?**

*Probes:*

*Which investment/analysis methods were used? (payback, ROI, ...)*

*Were these methods the same as used in other investment decisions within the business unit?*

*Did you have difficulty evaluating this decision within standard capital budgeting framework?*

*Costs: identified? measured? actual cost versus expectations? total estimate for the original system?*

*Benefits: identified? measured? actual benefits versus expectations?*

*Risks: identified? measured? actual risks versus expectations?*

*Did you have weighting for tangible and intangible aspects of the decision?*

**What, if anything, posed the single greatest obstacle to your business unit's justification of your automation project?**

**What, if anything, would improve and enhance the justification process for AMT?**

#### IMPLEMENTATION

**How has the implementation process been managed?**

*Probes:*

*How long has implementation been in progress? Estimate % complete. Target date? Phase completed? (system concept, justification, planning and design, implementation, operation, evaluation)*

*Was a detailed as-is study of the organisation prepared? How was it done? Who was involved? What was the output?*

*Was a detailed implementation plan prepared and followed?*

*Are project management methods used for scheduling and tracking? Which methods? Is the implementation tracked by time?*

*Is a steering committee used in the implementation?*

*Is an implementation project team used? Ad hoc or formal? Levels? Did composition of team change during past six months? Reasons for change and impact on the project?*



**Do you use outside consultants (system integrators) in the implementation process? What is their role?**

*Probes:*

*In what ways have consultants contributed most to your automation efforts?*

*What, if any, are the most significant obstacles consultants have posed to your automation efforts?*

**Please describe your relationship with vendors (suppliers) of AMT both positive and negative aspects.**

*Probes:*

*How have they contributed most to your automation efforts?*

*What, if any are the most significant obstacles vendors have posed to your automation efforts?*

**Describe the training and education process used in your business unit for workers and management involved in the implementation process.**

*Probes:*

*What types of training? Timing? How extensive? Who was involved?*

## **IMPACT ON THE ORGANISATION**

**Please describe the way in which automation has caused changes in your organisation**

*Probes:*

*change      no change      change*

*individual jobs*

*formal procedures*

*managerial responsibilities*

*interdepartmental relationships*

*organisational structure*

*power structure*

*decision process*

*performance evaluations*

*reward/incentive programmes*

*employee satisfaction*

*performance*

**What, if anything, posed the greatest obstacle to your business unit's implementation of your automated systems?**

**What, if anything, has been your business unit's single greatest strength in implementing factory automation?**

**In your opinion, what are the three most critical factors in a successful implementation of AMT?**

*Probes:*

*top management involvement and commitment*

*skills training for operators*

*education for all levels within the firm*

*vendor support*

*end-user involvement*

*outside consultants*

*detailed implementation plan*

*overall strategic plan*

*phased implementation*

*full-time project leader*

*formal project team*

*steering committee*

*understanding the manufacturing process*

## EVALUATION

**Are you satisfied with you factory automation systems?**

(rank 1 to 5, 1= very dissatisfied 5=very satisfied)

*Probes:*

*How do you measure satisfaction?*

*How do you characterise success or failure?*

*or*

*Formalised objectives were met*

*System "works" according to plan and/or in an acceptable manner*

*Anticipated benefits were realised*

*Unanticipated benefits were realised*

*or*

*Anticipated negative outcomes occurred*

*Unanticipated negative outcomes occurred*

**What benefits has your business unit achieved by implementing AMT?**

*Probes:*

*Strategic factors (customer demand, competitive edge new products..)*

*Operational factors (reduce WIP, lead time, labour, quality...)*

*Were there benefits related to managerial and/or organisational effectiveness?*

*What were they? How are they measured?*

**What, if anything, poses the greatest obstacle to the evaluation of your AMT system?**

## MANAGEMENT OF TECHNOLOGY

**Are you involved with the management of technology?**

*probes:*

*continuously develop and integrate new technology*

*exploit new technology from outside*

**What are the major issues concerned with the management of technology in your firm?**

*probes:*

*develop strategy*

*use technology as a competitive tool*

*external and joint development of technology*

**Are you opportunistic/proactive or defensive/reactive towards technology?**

*probes:*

*always pursue opportunity in technology related issues*

*react to competitive force s to adopt technology*

**What is your approach towards new technology developments?**

(rank 1 to 5, 1=not at all, 5=great deal)

a. Monitor Technological Developments

1. includes investment of the firm's resources in evaluating new technology and ideas, and systematically examining these ideas to see if they are suitable for use by the firm.

b. Support Technological Developments

1. extent of the firm's support in developing and adopting new technologies in manufacturing.

## **APPENDIX B**

### **BACKGROUND QUESTIONNAIRE**

#### **MANUFACTURING TECHNOLOGY MANAGEMENT**

This study is designed to determine how European manufacturers are adopting, implementing, evaluating and the management of manufacturing technology.

This brief questionnaire supplements the information provided by you during the interview. The purpose of this questionnaire is to get insights into your experience in implementing automated systems and information about your business unit and manufacturing environment.

All of the questions in the survey refer to a business unit. A business unit may be an entire company, a group, a division, or in some instances a plant, depending on the way your company is organised. In general, you should answer for the unit you know best. Whatever you choose as the unit of analysis, it is important that your answers consistently apply to the same business unit throughout the questionnaire.

If you encounter questions which you cannot answer or questions which do not apply, please leave them blank ( or indicate that they do not apply ). Answer the questions by checking or entering the most appropriate response as indicated. Your individual responses will be protected through the synthesis of responses of all firms participating in this research.

If you have any questions, please feel free to call me. Thank you for your participation in this research project.

## APPENDIX B

### BACKGROUND QUESTIONNAIRE

Name..... Title.....

Company.....

Address.....

Telephone Number..... Fax Number.....

1. Check the box which best describes the business unit.

- |                |                        |
|----------------|------------------------|
| a. .... Plant  | b. .... Division       |
| c. .... Group  | d. .... Entire Company |
| e. .... Others |                        |

2. What are the principal products manufactured by the company?

.....

3. What were the sales of the business unit of the last fiscal year?

- a. .... Under \$10 million
- b. .... \$ 10 - 50 million
- c. .... \$ 51 - 100 million
- d. .... \$ 101 - 500 million
- e. .... \$ Over 500 million

4. Estimate the overall net profit (loss) before tax as a per cent of sales (last fiscal year) for the business unit.

..... % of Sales

5. What were the manufacturing costs (material, labour, and manufacturing overhead) as a per cent of total sales (last fiscal year) for the business unit.

..... % of total sales

6. Estimate the current structure of manufacturing costs for a typical final product. (should add to 100%)

- a. .... % material
- b. .... % direct labour
- c. .... % manufacturing overhead

7. How many years has this business unit been operational?

a. .... years

8. Indicate the number of people (both hourly and managerial) employed in the business unit.

a. .... total number of people employed

9. Indicate your business unit capacity utilisation last fiscal year.

a. .... %

10. Which types of production processes occur in this business unit? Check the item which applies. If more than one type occurs, estimate each type's percentage of annual dollar output volume.

- |                         |         |
|-------------------------|---------|
| a. .... continuous flow | ..... % |
| b. .... repetitive      | ..... % |
| c. .... batch           | ..... % |
| d. .... job shop        | ..... % |

11. Does the business unit have a strategic plan?  
a. .... yes      b. .... no
12. Does manufacturing contribute to the strategic planning process for this business unit?  
a. .... yes      b. .... no
13. Is there a formal manufacturing strategic planning process within the business unit?  
a. .... yes      b. .... no
14. Was the decision to implement automation included in the manufacturing strategic plan?  
a. .... yes      b. .... no
15. Given your current situation, which of the following attributes strike you now as the one(s) that will have the greatest impact on improving your competitiveness in the future?  
Circle most appropriate number along each scale.
- |                                 |                  |   |   |   |   |   |                |
|---------------------------------|------------------|---|---|---|---|---|----------------|
| a. Improving quality of product | Very Unimportant | 1 | 2 | 3 | 4 | 5 | Very Important |
| b. On-time delivery             | Very Unimportant | 1 | 2 | 3 | 4 | 5 | Very Important |
| c. Provide fast deliveries      | Very Unimportant | 1 | 2 | 3 | 4 | 5 | Very Important |
| d. Lowering product cost        | Very Unimportant | 1 | 2 | 3 | 4 | 5 | Very Important |
| e. Offer broad product range    | Very Unimportant | 1 | 2 | 3 | 4 | 5 | Very Important |
| f. Make rapid product mix       | Very Unimportant | 1 | 2 | 3 | 4 | 5 | Very Important |
| g. Introduce new products       | Very Unimportant | 1 | 2 | 3 | 4 | 5 | Very Important |
| h. Offer customised products    | Very Unimportant | 1 | 2 | 3 | 4 | 5 | Very Important |
16. Why have there been some significant changes or reorganisations within your division's or company's function in the past 5 years? Please check box in order of priority. 1=top priority.
- ..... External competition (cost, quality)
  - ..... Changing nature of customer demand
  - ..... New technology introduced
  - ..... More globalisation in market demand
17. What are the changes that have been implemented over the last five years, or are currently being pursued in your division or company? Circle most appropriate number along scale.
- |                              |                 |   |   |   |   |   |                |
|------------------------------|-----------------|---|---|---|---|---|----------------|
| a. Quality systems           | Little Emphasis | 1 | 2 | 3 | 4 | 5 | Great Emphasis |
| b. Production systems        | Little Emphasis | 1 | 2 | 3 | 4 | 5 | Great Emphasis |
| c. Plant size                | No New Ones     | 1 | 2 | 3 | 4 | 5 | More New Ones  |
| d. Use of information Tech.  | Little Emphasis | 1 | 2 | 3 | 4 | 5 | Great Emphasis |
| e. New equip. and automation | Little Now      | 1 | 2 | 3 | 4 | 5 | More Now       |
| f. New product development   | Longer Now      | 1 | 2 | 3 | 4 | 5 | Quicker Now    |
18. List the three most important lessons learned in manufacturing in the last five years.
- .....
  - .....
  - .....
19. What is the relative degree of emphasis the business unit will place on each type of activity or programme over the next two years? Circle most appropriate number along each scale.
- |                                       |                 |   |   |   |   |   |                |
|---------------------------------------|-----------------|---|---|---|---|---|----------------|
| a. Giving workers more responsibility | Little Emphasis | 1 | 2 | 3 | 4 | 5 | Great Emphasis |
| b. Management training for all        | Little Emphasis | 1 | 2 | 3 | 4 | 5 | Great Emphasis |
| c. Quality management & systems       | Little Emphasis | 1 | 2 | 3 | 4 | 5 | Great Emphasis |
| d. Use of information technology      | Little Emphasis | 1 | 2 | 3 | 4 | 5 | Great Emphasis |
| e. Extensive use of automation        | Little Emphasis | 1 | 2 | 3 | 4 | 5 | Great Emphasis |
| f. Consider environmental issues      | Little Emphasis | 1 | 2 | 3 | 4 | 5 | Great Emphasis |
| g. Improve production process         | Little Emphasis | 1 | 2 | 3 | 4 | 5 | Great Emphasis |

This is the end of the questionnaire. Thank you for you time and patience. Please return the questionnaire in the enclosed freepost envelope to:

Suresh Balan  
European Institute  
French Geneva Campus  
Archamps, France.  
Tel. (33) 50315678 Fax. (33) 50315680

## APPENDIX C

### QUESTIONNAIRE: MEASUREMENT SCALES FOR INTEGRATED MANUFACTURING PRACTICES USING AMT

#### COMPUTER INTEGRATED MANUFACTURING (CIM)

To what extent are each of the following technologies used in your plant?

1. Manufacturing Resource Planning (MRP II).  
Not At All   1   2   3   4   5   Extensively
2. Computer Aided Design (CAD).  
Not At All   1   2   3   4   5   Extensively
3. Numerical Control (NC).  
Not At All   1   2   3   4   5   Extensively
4. Computer Numerical Control (CNC).  
Not At All   1   2   3   4   5   Extensively
5. Flexible Manufacturing Systems (FMS).  
Not At All   1   2   3   4   5   Extensively
6. Robotics.  
Not At All   1   2   3   4   5   Extensively
7. Automated Materials Handling (AGV & AS/RS).  
Not At All   1   2   3   4   5   Extensively
8. Computer Aided Test and Inspection.  
Not At All   1   2   3   4   5   Extensively
10. Computer Aided Process Planning (CAPP).  
Not At All   1   2   3   4   5   Extensively
11. Computer Aided Quality Control.  
Not At All   1   2   3   4   5   Extensively

#### TOTAL QUALITY CONTROL (TQC)

To what extent are each of the following quality concepts used in your plant?

1. Overall management concept to total quality.  
Not At All   1   2   3   4   5   Extensively
2. Co-operation with suppliers to improve quality.  
Not At All   1   2   3   4   5   Extensively
3. Process of mapping on cost of quality.  
Not At All   1   2   3   4   5   Extensively
4. Commitment to provide quality products.  
Not At All   1   2   3   4   5   Extensively
5. Use of statistical techniques to improve quality.  
Not At All   1   2   3   4   5   Extensively

6. Employee involvement in quality programmes.  
Not At All   1   2   3   4   5   Extensively
7. Constant feedback about quality to employees.  
Not At All   1   2   3   4   5   Extensively
8. Continuous improvement process in quality.  
Not At All   1   2   3   4   5   Extensively

### JUST IN TIME (JIT)

To what extent has each of the following changed in the past five years in your plant layout?

1. Reduction in set-up times.  
Huge Decrease   1   2   3   4   5   Huge Increase
2. Attention to reducing number of suppliers.  
Huge Decrease   1   2   3   4   5   Huge Increase
3. Increase number of deliveries.  
Huge Decrease   1   2   3   4   5   Huge Increase
4. Length of product runs.  
Huge Decrease   1   2   3   4   5   Huge Increase
5. Total number of different parts.  
Huge Decrease   1   2   3   4   5   Huge Increase
6. Reduction in amount of buffer stocks.  
Huge Decrease   1   2   3   4   5   Huge Increase
7. Product pulled through plant.  
Not At All   -   1   2   3   4   5   Extensively
8. Product laid out by process or product.  
Not At All   1   2   3   4   5   Extensively

## APPENDIX D

### QUESTIONNAIRE: MEASUREMENT SCALES FOR MANUFACTURING STRATEGY PROCESS USING AMT

#### ADOPTION

##### Formal Strategic Plan

1. Our plant has a formal strategic planning process which results in a written mission, long-range goals and strategies for implementation.  
Very Little   1   2   3   4   5   Great Deal
2. Plant management is not included in the formal strategic planning process. It is conducted at higher levels in the corporation. (Reversed Scale)  
Very Little   1   2   3   4   5   Great Deal

##### Long-Range Plan

1. Financial goals are the most important in the plant. (Reversed Scale)  
Very Unimportant   1   2   3   4   5   Very Important
2. There is a lot of emphasis on manufacturing costs targets. (Reversed Scale)  
Little Emphasis   1   2   3   4   5   Great Emphasis
3. Management outside of the plant is primarily concerned with short range financial performance. (Reversed Scale)  
Little Concern   1   2   3   4   5   Very Concerned
4. Our plant is long-run oriented and does not change its goals or objectives each year.  
Always Change   1   2   3   4   5   No Change
5. Short-term losses affect our decision making, but are less important than pursuing long-term goals.  
Very Important   1   2   3   4   5   Very Unimportant

#### IMPLEMENTATION

##### Communication of Strategy

1. In our plant, goals, objectives and strategies are communicated to me.  
Not At All   1   2   3   4   5   Extensively
2. Strategies and goals are communicated primarily to managers. (Reversed Scale)  
Not At All   1   2   3   4   5   Extensively
3. I know how we are planning to be competitive at this plant.  
Not At All   1   2   3   4   5   Very Well
4. I understand the long-run competitive strategy of this plant.  
Not At All   1   2   3   4   5   Very Well



### Co-ordination in Decision Making

1. Generally speaking, everyone in the plant works well together.  
Not At All   1   2   3   4   5   Extensively
2. Departments in the plant communicate frequently with each other.  
Not At All   1   2   3   4   5   Very Well
3. Department within the plant seem to be in constant conflict. (Reversed Scale)  
Always   1   2   3   4   5   Not At All
4. Management works well together on all important issues.  
Not At All   1   2   3   4   5   Very Well

### Centralisation in Decision Making

1. I can do almost anything I want without consulting my boss. (Reversed Scale)  
Not At All   1   2   3   4   5   Always
2. Even small matters have to be referred higher up for a final answer.  
Not At All   1   2   3   4   5   Always
3. This plant is a good place for a person who likes to make his own decisions. (Reversed Scale)  
Not Good   1   2   3   4   5   Very Good
4. Any decision I make has to have my boss's approval.  
Not At All   1   2   3   4   5   Always
5. There can be little action taken here until a supervisor approves a decision.  
Not At All   1   2   3   4   5   Always

## **EVALUATION**

### Manufacturing Strategy Strength

1. We have a regular system of monitoring plant performance against formal criteria.  
Not At All   1   2   3   4   5   Extensively
2. We have a well-developed manufacturing strategy in our plant.  
Not At All   1   2   3   4   5   Very Well
3. Our plant is well focused.  
Not At All   1   2   3   4   5   Very Well
4. We have products and/or processes which sometimes place conflicting demands on plant personnel. (Reversed Scale)  
Not At All   1   2   3   4   5   Extensively
5. Manufacturing provides competitive strength for our business.  
Not At All   1   2   3   4   5   Extensively

### Manufacturing Competitive Advantage

1. We actively develop proprietary equipment.  
Not At All   1   2   3   4   5   Extensively
2. At our plant, manufacturing is centrally involved in marketing and engineering decisions.  
Not At All   1   2   3   4   5   Extensively
3. All the functions of our firm are well integrated.  
Not At All   1   2   3   4   5   Very Well
4. There is a long-range focus, in order to acquire manufacturing capabilities to advance our needs.  
Not At All   1   2   3   4   5   Extensively
5. We make an effort to anticipate the potential of new manufacturing practices and technologies.  
Not At All   1   2   3   4   5   Extensively

Framework for scales adapted from (Schroeder, 1991).

## APPENDIX E

### QUESTIONNAIRE: MEASUREMENT SCALES FOR COMPETITIVE PERFORMANCE MEASURES IN MANUFACTURING

#### COST

To what extent are the following items used to calculate cost?

1. Labour.  
Not At All   1      2      3      4      5      Extensively
2. Materials.  
Not At All   1      2      3      4      5      Extensively
3. Unit cost of manufacturing.  
Not At All   1      2      3      4      5      Extensively

#### QUALITY

How is quality perceived in the final product?

1. Per cent defective or rejected in the final product.  
Very Unimportant   1      2      3      4      5      Very Important
2. Frequency of failure in the field.  
Very Unimportant   1      2      3      4      5      Very Important
3. Cost of quality.  
Very Unimportant   1      2      3      4      5      Very Important

#### DELIVERY

How is delivery performance perceived?

1. Percentage of on-time shipments.  
Very Unimportant   1      2      3      4      5      Very Important
2. Orders lost due to average delays.  
Very Unimportant   1      2      3      4      5      Very Important
3. Time spent on expediting response time.  
Very Unimportant   1      2      3      4      5      Very Important

#### FLEXIBILITY

How is flexibility perceived?

1. Ability to vary product mix.  
Very Unimportant   1      2      3      4      5      Very Important
2. Ability to provide volume flexibility.  
Very Unimportant   1      2      3      4      5      Very Important
3. Reduce cycle time for new products.  
Very Unimportant   1      2      3      4      5      Very Important

## APPENDIX F

### QUESTIONNAIRE: MEASUREMENT SCALES FOR FACTORS EFFECTIVE MANAGEMENT OF TECHNOLOGY

#### RECOGNISE STRATEGIC ROLE OF TECHNOLOGY

To what extent are each of the following perceived?

1. How technology intensive is our business?  
Not At All   1   2   3   4   5   Great Deal
2. How important is the strategic impact of technology on our business?  
Very Unimportant   1   2   3   4   5   Very Important
3. Is this reflected explicitly in the way we develop strategies?  
Not At All   1   2   3   4   5   Extensively

#### MANAGEMENT OF TECHNOLOGICAL PORTFOLIO

How does each of the following influence your business?

1. Have we the "right" technology mix given our business needs?  
Not At All   1   2   3   4   5   Great Deal
2. Have we incorporated all important technology in our business?  
Not At All   1   2   3   4   5   Extensively
3. Are we managing our technologies to exploit synergies?  
Not At All   1   2   3   4   5   Extensively

#### "HARD" SIDE OF TECHNOLOGY - INVESTMENT MANAGEMENT

To what extent are the following issues important?

1. Do we balance short-term and long-term demands effectively?  
Not At All   1   2   3   4   5   Great Deal
2. Does our allocation reflect the strategic importance of each technology?  
Not At All   1   2   3   4   5   Extensively
3. Are we making sure we do not over (under) invest?  
Little Emphasis   1   2   3   4   5   Great Emphasis

## "SOFT" SIDE OF TECHNOLOGY - INNOVATION MANAGEMENT

To what extent are the following issues important?

1. Do we organise for maximum technology effectiveness?  
Not At All   1   2   3   4   5   Great Deal
2. Do we stimulate our business to break new technological ground?  
Not At All   1   2   3   4   5   Great Deal
3. Do we identify and eliminate obstacles to innovation?  
Not At All   1   2   3   4   5   Great Deal

## APPENDIX G

### QUESTIONNAIRE: MEASUREMENT SCALES FOR THE BUSINESS PERFORMANCE MEASURES OF A FIRM

#### PROFITABILITY LEVEL

To what extent does the business unit meet the following?

1. Financial objectives.  
Very Little   1   2   3   4   5   Great Deal
2. Financial strength relative to similar business unit.  
Very Little   1   2   3   4   5   Great Deal

#### GENERATING INCREASED SALES

To what extent does the business unit meet the following?

1. Achieving sales objectives.  
Very Little   1   2   3   4   5   Great Deal
2. Creating future sales through customer satisfaction (quality, cost, technology).  
Very Little   1   2   3   4   5   Great Deal

#### CREATING NEW OPPORTUNITIES AND FACILITIES

To what extent does the business unit meet the following?

1. Providing opportunities for new markets.  
Very Little   1   2   3   4   5   Great Deal
2. Providing opportunities/infrastructure for development and production of new products.  
Very Little   1   2   3   4   5   Great Deal

## APPENDIX H

### QUESTIONNAIRE: RESPONSE BY INDUSTRY

	INDUSTRY				
	Computer/ Telecomm.	Automobile/ Machinery	Aerospace	Chemicals/ Pharmact.	Frequency Response
<u>Face-to-Face Interviews</u>					
Plant Manager	11	8	8	8	35
Fun. Mng.& Direct.	1	1	1	1	4
Project Mng.	2	1	1	1	5
Engineers & Others	3	2	1	1	7
Frequency	17	12	11	11	51
<u>Background Questionnaire</u>					
Plant Manager	11	8	8	8	35
Fun. Mng.& Direct.		1	1		2
Project Mng.	1		1	1	3
Engineers & Others	1	1	1	1	4
Frequency	13	10	11	10	44
<u>Manufacturing Strategy Framework Questionnaire</u>					
Plant Manager	11	8	8	8	35
Operations Mng.	8	7	6	8	29
Quality Mng.	10	8	7	7	32
Prodn.Mng.	9	7	6	5	27
Others	2	1	1	1	5
Frequency	40	31	28	29	128
<u>Management of Technology Framework Questionnaire</u>					
Plant Manager	11	8	8	8	35
Frequency	11	8	8	8	35

## APPENDIX I

### BACKGROUND AND PUBLIC DOMAIN INFORMATION

The increasing pressure on European manufacturers has resulted in massive restructuring within companies and this process is continuing on. A number of forces increasingly based on lowering product cost, the ability to deliver quickly and the ability to design and introduce new products at a relentless pace to meet customer demands, have driven them to do so. The background information from the questionnaire provide a general insight into how manufacturing executives are responding to the challenges facing them.

#### 1. Sales and number of employees of the business unit for 1991.

Most companies reported a reduction in the number of employees as compared to the previous year.

	INDUSTRY				
	Computer/ Telecomm.	Automobile/ Machinery	Aerospace	Chemical/ Pharmact.	Frequency
<u>Countries included in survey</u>					
Belgium				1	1
France	6	2	4	1	13
Germany		3	1	3	7
Italy	1	1			3
Netherlands	1		1		2
Switzerland		1		2	3
United Kingdom	3	1	2	1	7
Total	11	8	8	8	35
<u>Sales \$ (in millions)</u>					
< 100		1	1	1	3
100-500	2	2	1	1	6
501-1,000	4	2	2	3	11
1,001-10,000	3	3	2	2	10
> 10,000	2		2	1	5
Total	11	8	8	8	35
<u>Employees</u>					
< 1,000	2	1	1	1	5
1,000-5,000	5	2	3	2	12
5,000-20,000	3	4	3	5	15
> 20,000	1	1	1		3
Total	11	8	8	8	35



## 2. Manufacturing cost breakdowns for 1991.

Most of the industries reported there will be a continuous drive to reduce manufacturing costs as a percent of sales over the coming years. In terms of overall manufacturing cost structure, the biggest emphasis is on reducing material cost. There will be more closer working relationship with suppliers to achieve this.

	INDUSTRY			
	Computer/ Telecomm.	Automobile/ Machinery	Aerospace	Chemical/ Pharmact.
<u>Capacity Utilisation for 1991</u>				
% of Utilisation	78.5	77.5	70.3	72.7
<u>Manufacturing costs as % of sales 1991</u>				
1991	58.5	57.2	62.1	61.6
<u>Manufacturing cost structure 1991</u>				
% Materials	59.1	62.3	61.4	60.4
% Direct labour	19.8	15.2	17.6	17.8
% Mang. O/H	21.1	22.5	21.0	21.8
% Total	100	100	100	100

## 3. Role of manufacturing and automation in strategic planning process.

Most of the participants agreed that manufacturing plays a vital role in the strategic planning process of the company. With more globalisation and external competition, manufacturing will have a greater impact on the future business planning. Some responded that there was no written policy as such and might have hesitated to give a more positive answer. The role of automation is also of high significant importance in the manufacturing strategic plan, however the decision-making process was unclear to some of the participants who might have responded negatively.

Formal manufacturing strategic plan exists: Yes 84% No 16%  
Decision to implement automation in strategic plan: Yes 89% No 11%

## 4. Attributes having the greatest impact on improving competitiveness in the future.

Participants were asked to indicate on a 5-point scale the relative importance of eight specific capabilities to remain competitive in the future. The means of the rankings are given below. Improving quality and lowering product cost were seen as the main drivers.

(1=very unimportant, 5=very important)

Improving quality of product	4.56
Lowering product cost	4.48
Introducing new product	4.32
On-time delivery	4.21
Provide fast delivery	3.97
Offer customised product	3.63
Offer broad product range	3.54
Make rapid product mix	3.22

## 5. Reasons for re-structuring the organisation in the last five years.

Most of the firms have undergone and are still undergoing reorganisation in their businesses to remain competitive. This process is to continue at least for the next five years. External competition was singled out as the most important factor. Their ratings in order of priority are given below. (1=top priority)

1. External competition
2. More globalisation in market place
3. Changing nature of customer demand
4. New technology introduced

6. Changes that have been implemented or currently being pursued.

As stated earlier a continuous process of reorganisation is going on. Many processes have been implemented or still being pursued to gain better overall performance. There will be a continuous emphasis on quality and production systems over the coming years. On a 5-point scale the means of the responses are given below.

Quality systems (1=little emphasis, 5=great emphasis)	4.73
Production systems (1=little emphasis, 5=great emphasis)	4.52
Plant size (1=bigger now, 5=smaller now)	3.68
Use of information techn. (1=little emphasis, 5=great emphasis)	4.11
New equipments & automation used (1=little now, 5=more now)	4.21
New product development (1=longer now, 5 quicker now)	4.37

7. The most important lessons learned in manufacturing in the last five years.

Participants were asked an open-ended question to list the top three items they considered as the most important lessons learned in manufacturing in the last five years. The three most frequent answers are given below. Again quality comes as an important issue and it relates to the other answers as the most dominant character in manufacturing in the 1990s.

1. Importance of quality
2. Total employee involvement and communication
3. Overall cost reduction

8. Emphasis on the activities that the business unit will place in the next two years.

There is a continual improvement programme on the plant's activities to reach the "best performer" category for their industry. Respondents rated the following activities on a 5-point scale as the activities which will receive the greatest emphasis over the next two years. Quality management and management training were of top priorities. (1=little emphasis, 5=great emphasis)

Management training for all	4.62
Quality management & system	4.58
Extensive use of automation	4.45
Improving production processes	4.36
Use of information technology	4.22
Consider environmental issues	3.98
Giving workers more responsibility	3.87

## APPENDIX J

### OVERVIEW OF AMT SYSTEMS BY INDUSTRY

	INDUSTRY				
	Computer/ Telecomm.	Automobile/ Machinery	Aerospace	Chemicals/ Pharmact.	Frequency of Techn.
<u>Technology Application</u>					
MRP I	4	4	2	4	14
MRP II	6	7	6	3	22
CAD	11	6	8	5	30
NC	8	6	8	5	27
CNC	11	5	8	5	29
FMS	8	5	8	4	25
GT	5	5	1	1	12
JIT	6	5	3	5	19
TQC	9	6	6	5	26
CAPP	4	3	3	-	10
AGV	5	5	4	3	17
Robotics	10	5	8	6	29
Com. Test & Insp.	10	5	4	4	23
Com. Quality	8	6	7	5	26
Simulation	5	4	4	3	16
Other*	6	4	7	3	20
Freq. of Tech.	116	81	87	61	345

\* Other includes: facilities planning, SPC, AS/RS, laser, CAE, cellular manufacturing, expert systems.